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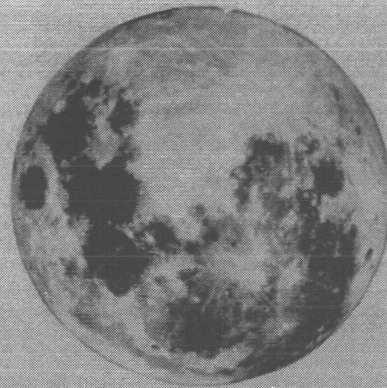
APOLLO APPLICATIONS PROGRAM

PAYLOAD INTEGRATION



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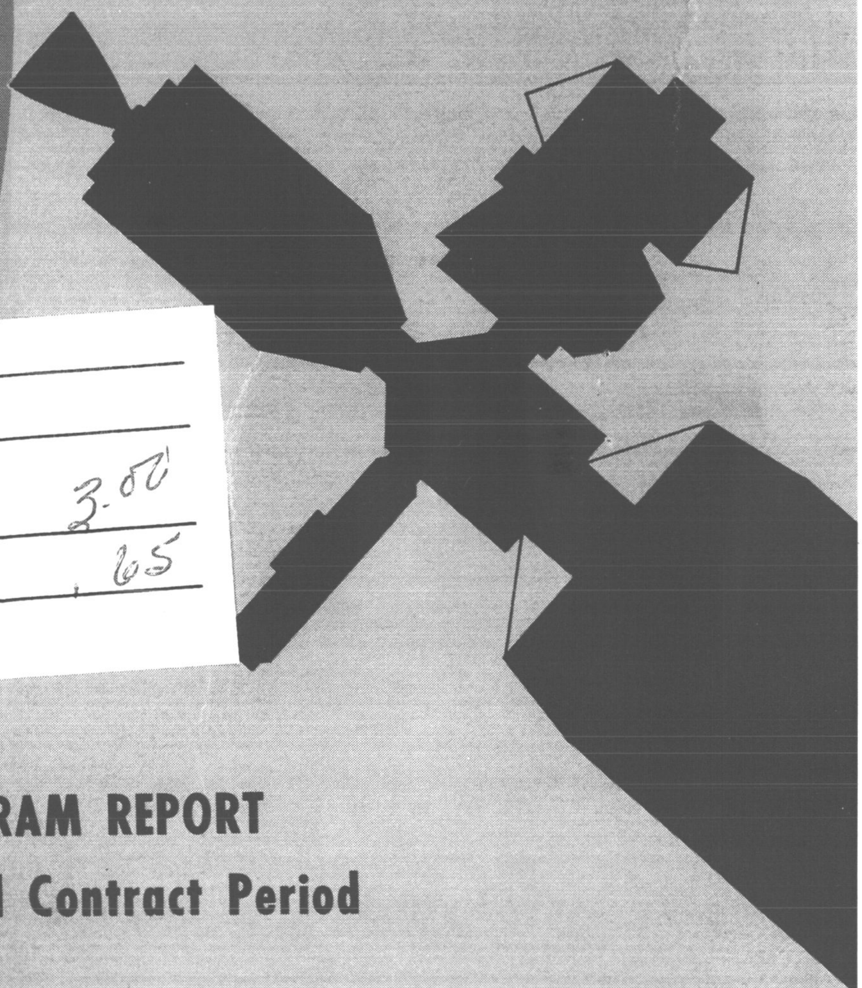

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PROGRAM REPORT
Second Contract Period

APRIL 13, 1967

MARTIN MARIETTA CORPORATION
DENVER DIVISION

PR 2003-3

Contract NAS8-21004

APOLLO APPLICATIONS PROGRAM PAYLOAD INTEGRATION PROGRAM REPORT

Second Contract Period

April 13, 1967

Approved

R. S. Williams, Director
Apollo Applications Program

MARTIN MARIETTA CORPORATION

FOREWORD

This document is submitted in accordance with the requirements of DRL Line Item 6 of Exhibit C of Contract NAS8-21004.

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During the second AAP contract period completed April 7, 1967, we conducted five major interdependent activities:

- Definition of the AAP payload integration development/ operations phase;
- Technical studies associated with our assignment, AAP Flights 2 and 4;
- Research of experiments and compilation of data associated with the proposed experiments;
- Special technical investigations assigned by MSFC;
- Definition studies of missions immediately following Flight 4.

Our Phase D proposal contains the results of definition of the payload integration tasks. Definition has involved technical and management studies in all program areas. Payload integration for AAP involves the many operational and hardware elements that must be coordinated. During Phase C we have established a pattern for management and technical communication that is compatible with established Apollo and MSFC practices.

Technical studies associated with the cluster mission have been our major effort during the past six months and included orbital workshop activation, thermal control, stabilization and pointing, electrical networks, mission operations, crew operations, test requirements, dynamic loads, GSE, and communications. We have also investigated such operational disciplines as facility activation, manufacturing, and quality to determine special requirements for performing payload integration. These investigations have been documented in study reports. (A complete listing of reports is contained in Chapter XI.)

The experiments proposed for AAP range from simple crew observations to the complexities of an ATM. Integration requires a specialized knowledge of each so the interfaces can be defined and controlled. We have researched all known experiments and cataloged our information as an aid to future activities. Several experiments that have been the subject of special studies are discussed in Chapter III.

At the direction of MSFC, we have engaged in a number of special studies. Although most of these have been associated with the first cluster mission, several relate to definition of unassigned missions. The synchronous orbit missions have received particular emphasis so suitable experiments can be defined and developed to meet the schedule.

As in the previous monthly reports, discussion of the activities of the Martin Marietta/Bendix team are combined. Additionally, Chapter X describes in detail the activities and reports generated by the Bendix groups during this six-month period. We believe that these reports are of particular interest to several laboratories at MSFC, and that they provide an indication of the depth to which the studies have been performed.

Our Phase C activities have been conducted in accordance with a plan prepared early in the program and maintained as required. All of these activities have been correlated and monitored in accordance with the event network shown in Figure I-1. A detailed discussion of the milestones and their control can be found in Chapter VIII.

The remaining three months of this initial contract are scheduled for additional technical tasks that are primarily associated with the cluster mission. We anticipate that these will blend into Phase D activities as we phase into the MSFC payload integration activities.

A. CLUSTER CONFIGURATION

1. General - An initial feasibility study of the cluster concept was conducted. This study, documented in ED-2005, Feasibility Study, Integrated Mission, ATM/Orbital Workshop, led to many more detailed studies.

a. Mission Compatibility - The preliminary analysis of the first four AAP flights was documented in 42-0001, Cluster Configuration Compatibility Analysis, dated December 17, 1966. This analysis evaluated the compatibility of a group of experiments with each other, the mission, specific carriers, schedules, etc. It is one level of detail greater than a grouping analysis, but is not sufficiently detailed to ensure that all problems have been resolved. In general, this compatibility analysis points out problems and indicates methods of solving them.

In this analysis, the mission, including launch vehicles, flight profiles, gross time scheduling, etc, was first described. Phasing of the rendezvous and estimates of the orbit decay of the various flights were then considered, followed by consideration of the assignment of proposed experiments to the cluster configuration carriers. The carriers assigned to each flight are:

1) Flight AAP-1 - Command and service module, lunar mapping and survey system rack, and instrument unit;
2) Flight AAP-2 - Airlock module, multiple docking adapter, orbital workshop, and instrument unit;
3) Flight AAP-3 - Command and service module, resupply module, and instrument unit;
4) Flight AAP-4 - Lunar module, ATM rack, and instrument unit.

The storage, operating, and disposal locations within the carriers were then established so the experiment and housekeeping support requirements could be determined for each carrier.

The individual and total requirements of the proposed experiments were identified and summarized for comparison with the capabilities of the carriers. The large variety of scientific and technological experiments involved in the cluster configuration impose a significant number of requirements on the carrier and/or carrier subsystems for proper experiment operation. The requirements considered in this study are listed:

1) Power for experiment operation (motors, heaters, data, etc);
2) Radiators for experiment and astronaut heat rejection;
3) Environmental control for proper experiment operation (temperature, pressure, humidity);
4) Data acquisition and storage;
5) Stabilization, attitude control, and pointing;
6) Equipment transfer devices, equipment mounting for launch, operations, and disposition, astronaut restraints;
7) Crew time and operating time, including setup and teardown time, EVA, IVA;
8) Controls and displays (may include some housekeeping functions);
9) Real-time communication and data transmission;
10) Weight and volume (launch and return);
11) Propulsion (plane or altitude changes).

A justification was prepared for each experiment location. (For each location selected for a particular experiment, reasons for that choice were given along with reasons for not using possible alternative locations.) This was followed by a summary of the special requirements and problems for particular experiments. An example is Experiment T004, Frog Otolith Function, which must be conducted in the first 72 hours of flight before the frog dies.

Many experiments impose constraints on the mission plan, subsystem operations, and recovery operations. In performing the compatibility analysis, these experiment-peculiar constraints were identified and reconciliation attempted. The following list illustrates the significant constraints that were evaluated:

1) Zero- or a specific level of gravity;
2) Stabilization and pointing;
3) Orbit attitude and inclination;
4) Precise environmental control;
5) Inhibiting RCS engines;
6) Data storage and recovery;
7) Maneuvers;
8) Electric power;
9) Experiment time;
10) Rendezvous and docking.

Experiment time requirements were integrated with mission profile, crew rotation cycles, and housekeeping functions by hand analysis. Such experiment performance constraints as day and night, opportunities for celestial or earth sightings, and real-time data transmission were first determined by an orbit simulation model. The orbit-constrained opportunities established by orbit simulation were integrated with the performance requirements of other experiments by hand scheduling. The desired experiment schedule requirements were determined through the experiment analysis previously described. These desired schedule requirements were then allocated to a mission day for tentative performance. Smoothing of the daily assignments without compromising requirements was done next. For this exercise, each experiment was viewed as though it were the only experiment carried. The daily experiment time and resource requirements thus determined served as a baseline for the integration.

The second step in scheduling was to combine common experiment activities and functions without compromising experiment requirements. This included combining EVAs and other common activities to save preparation and suiting time while conserving experiment carrier resources. Experiments compatible with simultaneous performance and those that can be performed during watch periods were combined. Other experiments were scheduled for performance by one man instead of two. Through this combining process, the desired experiment schedule requirements were reduced to the minimum possible without compromising the performance objectives of the experiments. When the daily requirements of the experiment group still exceeded the available time and carrier resources, several courses of action were considered and decisions reached as to which course to follow. These included:

1) Reduce experiment performance time;
2) Change the mission plan or profile;
3) Provide automatic controls for some experiments;
4) Delete experiment from group.

The third step in the integrated time-line development was to generate alternative schedules or alternative paths that could be used in the decision process. These alternatives were stated in the analysis report.

Mismatches arose in all of the three areas of requirements, constraints, and scheduling, and from interaction between these areas. To establish the mismatches, the total requirements of each experiment group were compared with the carrier's capability, the mission plan, subsystem operations, and recovery operations. Each experiment was also compared with other experiments in the group. After establishing the mismatches, detailed analyses were made in each subsystem area -- data management, communications, guidance and control, propulsion, life support, thermal control, power, and displays and controls to evaluate the mismatches and to propose solutions of the mismatches. Where necessary, the effects of solutions on other subsystems were iterated through the system.

In parallel with the mismatch evaluation, experiment and add-on system installation layouts were made to determine the suitability of the selected locations and to arrive at alternative locations where necessary. This was paralleled with structural and weight analyses as required. The weight summaries were compared with vehicle payload capabilities to evaluate the payload margin available.

A special feature of this study was an analysis of crew activities. This included analysis of the operational requirements and a detailed evaluation of the impact of experiment requirements on the crew. In fact, Volume 2 of 42-0001 is devoted entirely to detailed breakdowns of the tasks involved in experiment operations. A large number of mismatches and discrepancies in the experiment time allowances were uncovered. The report will be revised and issued as ED-2002-31.

As part of the compatibility analysis, display and manual control functional requirements were determined, by flight, for all vehicles in the cluster. Experiments and add-on equipment were reviewed and analyzed to determine the display and control panels necessary to support the AAP flights. The functional requirements were then translated into preliminary panel layouts and mockup analyses were conducted. Once the display and control requirements were identified, an analysis to determine the functional interface between the various cluster vehicles was conducted. Display and control interface schematics were generated and a wire count established between cluster vehicles.

b. Fire Detection - A preliminary study report, ED-2002-21, Analysis of Fire Detection for the Orbital Workshop, summarizes the requirements for fire detection in the OWS and anticipated modes of fire, and surveys and recommends systems that could be used to detect incipient fires. Since certain OWS environmental factors have not been clearly established, i.e., cable cordage, atmospheric flow pattern, etc, the report suggests further equipment investigations, with particular emphasis on ultraviolet and particle detectors.

This report was followed by ED-2002-32, Proposed Fire Detection System and Test Plan. The report proposes use of the particle detector for the OWS and presents preliminary system capability, and installation and data storage requirements. It also includes test programs for flight qualification of the particle detector system and evaluation of the detector in a simulated orbital workshop. Such test programs are considered highly desirable to determine the adequacy of the proposed system.

A preliminary procurement specification was submitted as report ED-2002-37, Fire Detection System Equipment Specifications. This is a preliminary procurement specification document (AAP 1071) that may be given to potential vendors for their technical proposals for and pricing of a combustion product ionization detector. The specification is preliminary to the extent that additional technical data must be inserted. It was concluded that such data can be obtained only by subjecting flammable materials in the orbital workshop to laboratory tests simulating the OWS environment.

c. ATM Pointing Accuracy - Studies were performed to determine the capabilities of the hard-mounted ATM control system (fine-pointing control system) and to verify the ability of the vernier control system used in conjunction with the fine-pointing control system to meet performance requirements in the presence of short-period disturbances (i.e., crew motion and fuel slosh). Two cases were considered:

1) The ATM experiment package is isolated from the cluster by a limited two-degree-of-freedom flexible pivot. This study is documented in ED-2002-81, Single-Axis Cluster ATM Pointing Accuracy Study - Gimbaled Case;
2) The ATM experiment package is hard-mounted to the ATM rack and the cluster is controlled by the control moment gyros (CMGs). This study is documented in ED-2002-80, Single-Axis Cluster ATM Pointing Accuracy Study - Hard-Mounted Case.

Single-plane models of the vehicle and control system were used to simulate the pitch and roll axes, and a three-dimensional model was used to simulate the CMGs. The vehicle models included both rigid- and flexible-body dynamics. The control system model included sensor noise, and sensor, electronic, and actuator dynamics and nonlinearities. Crew disturbance forces obtained from a crew motion simulator were used as the primary system forcing functions.

For the gimbaled case, the effects on system performance caused by disturbance torques transmitted through the fine-pointing control system to the gimbaled ATM experiment package were evaluated. The major conclusion of the study is that the gimbal-mounted system can meet the performance requirements of 2.5 arc-sec and 1 arc-sec/sec in spite of unrestricted crew motion.

For the hard-mounted case, the effects on performance caused by variations in sensor and actuator dynamics, gain, noise level, and vehicle stiffness were evaluated. The major conclusions of the study are:

1) The hard-mounted system cannot meet the performance requirements of 2.5 arc-sec and 1 arc-sec/sec if crew motion is unrestricted;
2) Flexible-body dynamics markedly influence system accuracy and stability;
3) The hard-mounted system is suitable as a backup mode of operation provided crew motion is restricted.

A three-axis simulation study is being conducted to corroborate the results obtained with the single-axis study.

d. <u>Docking Loads and Orbit Transfer Maneuvers</u> - A docking loads and orbit transfer maneuver study conducted was reported in ED-2002-51. This report presents transient on-orbit docking loads for seven AAP configurations, as well as orbit transfer loads for two configurations. The loads are required as input for feasibility and structural design studies. Docking loads arise from an initial relative velocity between the docking vehicle and basic workshop at the moment of contact. The orbit maneuver loads are generated by CSM engine ignition and shutdown.

e. <u>Performance and Design Requirements</u> - A general specification, RS200000, that defines the performance and design requirements for Flights AAP-1 thru -4 was prepared. The document is a general report, in specification format, defining the baseline for all planning functions by Martin Marietta during the Phase C effort. The report provided a basis for similar NASA definition of Flights AAP-1 thru -4.

The specification establishes requirements for the design, development, and test of all mission elements beyond the scope of the basic Apollo program. This document imposes requirements on the basic Apollo program only to the extent necessary to allow accomplishment of the defined mission.

f. Interface Data - Subsystem functional schematics, MD-80-0018, were prepared to depict baseline on-orbit configurations for Flights AAP-1 thru -4. Each schematic portrays the total operational cluster configuration and defines the physical interfaces between carriers, subsystems, and experiments. The schematics also relate major subsystem components to other subsystems and components, and the AAP add-on systems to the basic Apollo configuration.

Mission functions and interfaces from Flight AAP-1 LM&SS operations through the Flight AAP-4 LM/ATM rack operations are specified, including S-IVB orbital workshop experiment reactivation during Flight AAP-4.

An updated set of schematics has been prepared and is available for program use.

In addition, experiment-to-carrier interface documents were prepared for several OWS experiments. These were in three volumes for each experiment -- physical, functional, and procedural interface control documents.

g. Communications - Another area of special emphasis was communications. Cluster antenna coverage, RF system utilization, MSFN utilization, and data dump time-lines were studied in detail.

A hardline voice intercom system was recommended to provide communications between all manned vehicles of the cluster and an informal report giving the recommended implementation of this system was issued.

A detailed data dump time-lines prepared for Flights AAP-1 thru -4 were used to determine the RF utilization profiles, and to conduct the data load analysis for MSFN stations. Report ED-2002-79, describing the MSFN ground station utilization, was issued.

The feasibility of extending carrier-to-ground contact times by using Apollo range-instrumented aircraft (A/RIA) as relays was analyzed. A report, ED-2002-77, was issued delineating the modifications necessary to permit relay operation.

Another study was conducted to define uplink command requirements. It was determined that UHF command capability should be added to Guam and Ascension to meet the AM requirements during Flight AAP-2 and the ATM requirements during Flight AAP-4.

2. Flights AAP-1, -3, and -4 - Several documents applicable to Flights AAP-1, -3, and -4 have been prepared. These are described in the following paragraphs.

a. Design Reference Mission Document (DRMD) - A DRMD was prepared for each flight. These documents, ED-2001-2, -3, and -4 were prepared in six volumes each.

Each DRMD defines a particular flight of the Apollo Applications Program. These documents present a comprehensive description of mission activities from prelaunch through postflight data analysis and reporting. Factors that must be considered to achieve the overall objectives are identified, including trajectory shaping, integrated mission activity time-lining, and vehicle attitude time-lining. Operational guidelines and constraints that must be observed, support requirements that must be provided, and alternative mission plans for contingency situations that could arise are presented.

The documents are intended to serve as a basis for future detailed operational planning of mission factors peculiar to the experiment integration task.

b. Design Plans - Separate addenda have been issued to supplement the general design plan for Flights AAP-1 thru -4. These flight addenda define and schedule the specific design tasks necessary for implementing a specific flight. The design tasks are identified irrespective of the contractor or NASA agency responsible for their satisfaction.

c. Mission Requirements Documents - Mission requirements documents were prepared for each flight. Each document establishes the general mission requirements for a specific AAP flight and defines the mission in general terms including objectives, flight plan and profile, and operations support. Spacecraft and launch vehicle requirements developed by mutual NASA center agreement are included to ensure compatibility. The mission requirements document is used as a guide for preliminary mission planning and detailed trajectory shaping.

d. Resupply Study - The mission configuration using a resupply module results in a negative payload margin of 963 pounds. A comparative analysis, ED-2002-55, evaluates several mission configurations to select the most favorable means of redistributing the resupply consumables from Flight AAP-3 to other flights of the mission and to restore the mission to feasibility.

3. Flight AAP-2 - Documents similar to those described in Subsection 2 were prepared for Flight AAP-2. Additional documents and studies for this flight are summarized in the following paragraphs.

a. Hardware Requirements Document, ED-2002-26 - This document establishes the design requirements for AAP-2 ground and flight hardware. The document establishes the authority for the AAP-2 end-item specifications, interface control drawings, and end-item modification specifications. It was provided at the request of MSFC and forms the basis for their documentation (of the same name) to control Flight AAP-2 hardware development. The data contained in the document are extracted from the General Specification, RS200000, and tailored to meet MSFC document requirements.

b. S-IVB CEI Specification, ED-2002-27 - This addendum specification to Douglas Specification CP 208009A establishes the requirements for performance, design, test, and qualification of the S-IVB orbital workshop (OWS). The addendum was prepared to provide all cognizant personnel associated with design, development, manufacturing, checkout, test, and management with a single document containing the performance, design, test, and qualification requirements to be used for S-IVB OWS development.

This document, along with a mission requirements document and a hardware requirements document, was prepared to start the MSFC documentation for the OWS flight.

c. OWS Hardware Requirements Document - This document was prepared at the request of MSFC to provide them with a means of controlling OWS development. It is an extraction from the General Specification, RS200000. The document establishes the requirements for performance, design, test, and qualification of an S-IVB orbital workshop. This first-level hardware document includes the general information necessary to define the overall flight vehicle and identifies each of the experiments to be included in the S-IVB orbital workshop as of the date of issue.

d. S-IVB Modifications - Modifications to make the spent stage suitable for on-orbit conversion to an orbital workshop are summarized in ED-2002-22. These modifications include those already recognized by MSFC and those resulting from Martin Marietta's studies of the activation of the orbital workshop and corollary experiment integration. The modifications will minimize the astronaut's task of converting the spent stage to a habitable workshop but will neither compromise the S-IVB's primary function as a booster nor interfere with passivation.

The information in this report will be updated and included in the final submittal of ED-2002-6, Sequence Analysis, Activation of Flight AAP-2 Orbital Workshop.

B. UNASSIGNED MISSIONS

1. General - In addition to work on the cluster and it's flights, the other missions in the Apollo Applications Program were studied. These are described in the following paragraphs.

a. General Design Reference Mission Document, ED-2001 - This document presents, in general terms, the missions of the overall Apollo Applications Program. It is the intent of this document to describe each flight of each mission, stating overall objectives, identifying vehicle usage and experiment payloads, and presenting a sequence of major flight maneuvers and events. This document is provided to serve as a guide for future detailed planning of each flight in the program.

b. Carrier Selection - ED-2002-2, Carrier Selection Study, Volume I thru VI, presents the results of studies and analyses conducted to determine the problems of integrating experiments into the various proposed experiment modules to be used in AAP missions, including comparisons of these modules for integration of various types of experiments and missions.

This study provides conclusions and recommendations regarding the specific hardware that should be used in each of the missions outlined in current mission plans; baseline carriers that meet the integration requirements; standardized experiment carrier modules that result from the envelope of requirements for all of the missions in which the carriers are to be flown;

standardized add-on modules representing the shopping list of subsystem equipment from which the experiment support subsystem may be derived; and the effects of costs on carrier selection determined during this study.

The recommendations are based on detailed analysis of the program identified at the start of the study, which consists of 11 unique missions involving 16 separate S-IB launches and six Saturn V launches.

An updated report, ED-2002-59, Mission Feasibility Analysis, defines carriers, carrier capabilities, experiment requirements, and the subsystem add-ons required to accomplish the 34 AAP missions starting with Flight AAP-5. Its purpose is to identify special problems for future mission planning. As such it provides a basis for generating the design plan and the design and development plan for the unassigned missions. It also provides a reference for development of the facility plans, test plans, etc, for the unassigned missions.

c. General Design Plan, PL-2002 - This document defines general design criteria and engineering tasks for all AAP flights for which MSFC has the integration responsibility. These identified design criteria and tasks to be performed establish the technical approach to be followed during the program definition phase activity for all missions. Tasks to be performed by all agencies associated with the AAP program are identified, including NASA, the integrating contractor, and all hardware contractors. Methods, procedures, and requirements for implementing the specified tasks are included where necessary for clarity.

d. Experiment Documentation - A Payload Development Document, CX200300, was prepared to provide a requirements specification containing data for use by experiment designers to ensure integration compatibility and preserve spacecraft operational integrity.

The document title was subsequently changed to "Experimenter's Guide" and the document was changed to present general program information essential to experimenters during concept, preliminary design, and early equipment development. This information includes the environments to be expected; basic information about each carrier and its supporting subsystems; the roles of the program participants (NASA, experimenter, payload integration contractor); the experiment integration sequence; definition of test facilities, including GSE made available by the payload integration contractor and GSE to be supplied by the experimenter; test operations; quality and reliability assurance requirements; logistics and support considerations; special requirements for crew operations; and a list of pertinent reference documents for the Apollo program.

An Experiment Data Handbook, ED-2002-4, and an Experiment Requirements Document, ED-2002-71, were also prepared. Each of these reports is a compilation of experiment descriptions. The objective of both reports was to present to MSFC current experiment descriptions. Each report categorized the experiments into biomedical/behavioral/bioscience, astronomy, space environment, zero-g thermodynamics, lunar surface, communications/navigation, remote sensors, space station development, and space operations. The Experiment Data Handbook contains summary descriptions of 154 experiments in the above nine categories, while the Experiment Requirements Document includes 143 descriptions.

e. GSE - ED-2002-72, Ground Support Equipment Implementation Plan, was prepared to identify the GSE required at MSFC, KSC, and at a thermal vacuum facility to support the AAP.

Existing Saturn/Apollo equipment usage and modifications of existing equipment were discussed. The need for new equipment resulting from AAP-peculiar carriers was identified.

Implementation of equipment defined for Flight AAP-1 thru -4 in regard to Flights AAP-5 thru -38, and problem areas resulting from repeated launches, including LC 39 considerations, were discussed and possible solutions delineated.

The analysis performed indicates that the GSE required for launching Flights AAP-1 thru -4 will satisfy the majority of requirements for launches of Flights AAP-5 thru -37. GSE mobility is an important consideration when the AAP-peculiar carriers are involved in several launches from LC 34, LC 37B, and LC 39. In addition these carriers are tested at MSFC, at a thermal vacuum facility, and at laboratories remote from MSFC.

2. Synchronous Missions - ED-2002-11, Experiment Selection for Synchronous Orbit, presents a list of candidate experiments for two separate synchronous-orbit flights previously designated 510 and 515, are scheduled late in 1969 and the other early in 1971. A secondary objective was to identify carrier modifications resulting from the experiment requirements.

The report was based on two ground rules that specified the first mission as then understood: (1) the experiment carrier would be the LM ascent stage, with the descent stage replaced by a rack, and (2) barbecue maneuvers would not be required for maintaining thermal balance since other techniques would be available. The report did not consider biomedical experiments since these would be performed in the command module.

To assess experiment feasibility, the natural and induced environment surrounding the spacecraft was analyzed. Special note was taken of the radiation environment occasioned by the increasing solar flare activity starting in 1968. The scattering and absorption introduced by the local environment and its effect on the optical experiments were evaluated.

Optical experiments were grouped according to pointing-accuracy requirements. For example, one group, the Apollo telescope mount requires pointing accuracies on the order of seconds of arc. This group presumably would be the first stellar-oriented ATM payload affording an opportunity to perform astronomical experiments from synchronous orbit.

A second group of experiments was identified as physics, astronomy, and multidiscipline (PAM). This group has less stringent pointing requirements, yet needs manned operation at synchronous altitude.

The selection of add-on modules necessary for existing subsystems to satisfy experiment requirements was discussed in some detail. The selection was based on the use of available certified hardware and, wherever possible, Apollo-qualified components and subsystems.

The capability of a Saturn V booster to place a large laboratory in synchronous orbit is an intriguing possibility. A laboratory could stay in position almost indefinitely. With resupply and maintenance of the life support and experiment equipment, the laboratory could be used for many years, allowing changes to be made in the experiments as astronomical knowledge increases. A true permanent space station, relatively safe from intense radiation (at 20,000 miles) and relatively fixed over the earth's surface thus becomes a possibility. The station would be far enough from earth to allow great visibility of the celestial sphere and would avoid the effects of earth-created or earth-scattered environment and background. (The solid angle subtended by the earth equals approximately $1/144 \times 4\pi \cong 0.09$ steradians.)

The earth's magnetic field will be down to between 100 and 200γ, and the gravitational field anomalies will be very small since the earth appears as almost a perfect sphere of uniformly distributed mass, or as a point attracting mass with a $1/r^2$ field. Orbital velocity is about 10,000 fps and the swing, spacewise for parallax measurements, is almost 50,000 miles per day. The clearness of space, combined with the length of time an astronomical object can be viewed, allows astronomical measurements for long periods of time. A man is required to choose targets, ensure continuous performance, make adjustments, and react to the events and opportunities presented. The construction of a large antenna for radioastronomy is also possible in a synchronous orbit. A man is needed for antenna alignment and repair although operation can continue unmanned. Placing the laboratory in an orbit so a single ground station can maintain continuous communications with it will allow unmanned operation between periods of occupation for many of the experiments.

The presence of men aboard the spacecraft necessitates consideration of contamination and crew motion disturbances. The discharge of liquid matter must be controlled to avoid coating critical surfaces and clouds of ice crystals that will reflect light into sensitive instruments. As with the ATM, the precision-pointed platform must be isolated from the disturbances caused by crew motions. Since the synchronous orbit laboratory will be in free fall, structural stresses would be caused only by inertial effects and the torque rates for telescope pointing would not be as great as those for telescopes in lower earth orbits. This will allow simple structural concepts for telescopes and large antennas. Drag forces are negligible -- the solar radiation pressure is the largest force of this kind.

We have selected experiments that can be accomplished in the time periods for Flights 510 and 515. They will serve as prototypes for a more permanent 24-hour manned scientific laboratory for use in the 1970s and 1980s.

The experiments chosen for Flight 510 are:

1) Laser optical communications;
2) LM relay experiments;
3) Day-night camera;
4) Observation of noctilucent clouds;
5) Measurement of resonance scattering in the earth's atmosphere;

6) Navigation and weather photography from synchronous orbit;

7) Hydrogen-maser clock.

The synchronous orbit allows sufficient time for the crew to prepare a laser communications experiment and will allow continuous operation. The inclination of the orbit allows use of several ground stations in case of weather problems. The LM relay experiment will be used to prove the feasibility of communication between a ground station and a CSM in low orbit. The only addition the LM will require is an 18-pound S-band transponder. The CSM in the low orbit will require modification to add a 100-pound, 10-foot-diameter antenna.

An image orthicon system relatively insensitive to variations in illumination intensity will be checked for widescope weather measurements as compared with a high-resolution (12-in. focal length) camera. The system of storing and dumping data from the image orthicon system will also be exercised for synchronous orbit.

In the navigation and weather photography experiment, high-latitude navigational points on the earth will be accurately placed by photography using a camera and a sextant. Location of various weather features at high latitudes will be determined.

Noctilucent clouds are high (80 km) dust clouds about 2 kilometers thick and consist of 1-micron particles. They will be surveyed from the 24-hour orbit, using a 20-centimeter focal length camera.

Measurement of resonance scattering in the earth's atmosphere takes advantage of the observing altitude to permit wide-angle observations. The scattering is caused by such minor constituent atom-ion species in the atmosphere as Li, Na, K, Ca^+, Si^+, Fe^+, Na^+ and Mg^+. From the 24-hour orbit, the use of a curved-slit Fastie-Ebert spectrometer of high resolution in the spectral range between the far UV and the near IR (below 1μ) allows a wide-range survey. Man is necessary to set up and align this high-precision spectrometer.

The hydrogen-maser clock experiment will verify the relativistic effects due to difference in the potential energy of two hydrogen masers, one operating at the earth's surface and one operating in the greatly reduced (factor of 36) gravitational potential at a 24-hour orbit.

For Flight 515, we have selected experiments grouped into two categories depending on pointing accuracy requirements:

1) ATM,
    a) Forty-in. telescope,
    b) Far infrared stellar spectrometer,
    c) X-ray telescope,
    d) Detection and measurement of a lunar atmosphere,
    e) Observation of Martian upper air dry ice layer,
    f) Infrared spectrometer observation of Mars and Venus;
2) PAM,
    a) Extended UV stellar survey,
    b) Extended celestial survey,
    c) Solar constant measurement,
    d) Erectable antenna for radioastronomy,
    e) Extended optical technology.

The most important long-range objective of the AAP scientific programs may be the development of large diffraction-limited telescopes for astronomical research. Wavelengths of electromagnetic radiation, which do not penetrate the earth's atmosphere, will receive extended study. The 40-inch telescope is the first step in manned orbital stellar observations and results of this experiment will determine the course of future astronomical research. Accuracies of 0.1 second of arc are possible and the undisturbed spacecraft will allow us to take full advantage of this higher pointing accuracy.

The far infrared stellar spectrometer is another example, in a different frequency range, where unobstructed and continuous view of most of the celestial sphere is of great importance. An X-ray telescope will be required both to determine physical conditions within known sources and to detect the X-ray emissivity of unusual optical and radio sources. Sources selected by the astronaut for observation will be based on results of previous X-ray surveys.

The detection and measurement of a lunar atmosphere involves the measurement of resonance-scattered radiation from solar-illuminated atoms or ions in the lunar atmosphere. These measurements will be performed at the synchronous orbital location by employing lunar disc occultation techniques. A Fastie-Ebert spectrometer will be used for special scanning and resolution, and a 10-inch Cassegrain telescope for imaging purposes. The accurate pointing requirement can be met by an astronaut.

The existence of a layer of frozen carbon dioxide $\left(CO_2\right)$ particles in the Martian upper atmosphere around the 80-kilometer level has been postulated. Using a technique similar to that suggested for the observation of noctilucent clouds, the possibility of observation appears attractive. As in the noctilucent cloud case, successful detection of particulate matter at high altitude depends on the presence of material below these heights to absorb the incident solar energy. This experiment should be performed in a manned mission to eliminate the need for automatic pointing and control equipment.

The infrared spectrometric observations of Mars and Venus would consist of both near-infrared and far-infrared spectrometric observations of the planets. From observations of the near-infrared reflection spectrums, it will be possible to infer CO_2 content, surface pressure, water vapor content, surface composition, presence of organic matter, cloud composition, and CO_2 and water vapor content above the clouds. From observations of infrared emission between 8 and 12μ, the horizontal distribution of surface temperature on Mars and of cloud temperatures on Venus could be inferred.

The objective of an extended UV stellar survey will be to obtain stellar spectra of sufficient resolution to permit the study of the ultraviolet line spectra, and to conduct a sky survey for young stars. The optical system for this experiment consists of an f/3.0, 6-inch aperture Ritchey-Chretien objective with two interchangeable dispersing elements. The astronaut will point the spectrograph at predetermined star fields, and will follow a prescribed exposure sequence. The X-ray survey will continue the program of X-ray astronomy by the study of galactic X-ray sources. The crew is required to recognize patterns and detect abnormalities.

The goal of the solar constant measurement experiment is to measure the total energy from the sun in the spectral region from 0.15 micron to 25 microns. Synchronous orbit is desirable for this experiment since there is an extended period for observation of solar radiation during each orbit, and the orbit is sufficiently distant from earth that radiation originating from the earth's surface will not contaminate the measurement.

An antenna for radio astronomy would be too large to erect in low earth orbit because of atmospheric drag. In addition, the time required to point an antenna of this size would preclude its operation in a short-period orbit. The functions of the crew in this experiment will include antenna pointing, antenna alignment, antenna tuning, and alignment of associated signal-conditioning equipment.

The extended optical technology experiment will space-qualify large-aperture optical systems and their associated stabilization subsystems. Qualification of a diffraction-limited large-aperture telescope system at synchronous orbit will allow long observation periods to study faint stars and distant galaxies. Following the qualification, the crew will deploy and orient the telescope system and acquire prescribed targets to test the telescope's fine-pointing system.

Our study shows that a manned laboratory in a synchronous orbit will be a productive scientific endeavor.

3. 1969 Missions - An analysis is being conducted to help define the 1969 low earth-orbital flights. An initial list of 15 mission alternatives with candidate experiment groups was prepared and presented to the Mission Planning Task Force in February 1967. Since that meeting, work to refine the definition of the LCSM, its impact on the 1968 cluster, and to evaluate logical experiment candidates has been continued. The selection of experiments that require long missions and the determination of which experiments from the 1968 cluster most logically should be reactivated and rerun has been emphasized.

After the list of mission modes is narrowed to a single alternative, the mission, the configuration of the vehicles involved, the system add-ons or modifications needed, and the experiment list will be further defined. The end result of this study will be design reference mission documents for each flight.

A. EO-2 (APP-A) WITH ATM

The feasibility of combining the EO-2 (APP-A) group of experiments with the ATM experiments has been investigated. The initial studies were documented in a feasibility analysis report with three supplements.

This analysis investigated the feasibility of mounting the EO-2 group of meteorological experiments with the ATM group of experiments on a common experiment carrier and performing them in a common mission. The analysis also determined whether the EO-2 group of experiments could be mounted in a common package on a carrier as opposed to individual installation of the experiments at dispersed locations on the experiment carrier.

The analysis indicated that both of the above configurations were feasible under the ground rules that existed at that time. Though an orbit exists that would allow hard-mounted solar experiments and earth-oriented experiments to be simultaneously pointed at their desired targets, it is impractical, and time sharing of the mission for both objectives is recommended.

The analysis was subsequently updated to reflect the further definitions of the cluster mission. This was documented in ED-2002-16, Feasibility Analysis of Combining APP-A Experiments with ATM. It was desired to determine what problems and constraints are imposed on the cluster by such a grouping and what order of magnitude of interface commodities must be available from the cluster to support performance of the package. The conclusion reached is that the suggested configuration is not feasible because of excessive pointing requirements for the complete cluster and the limitation on available resupply commodities.

B. EMR

A feasibility analysis, ED-2002-30, was conducted to study various ways by which the EMR experiment group could be integrated into the AAP. The requirements data document, 42-0002, provides detailed experiment analyses for each EMR experiment that can be used as backup data for the feasibility analysis.

The objective of the study was to check various carriers and missions of the AAP and recommend the most feasible for accommodating the EMR experiment group.

The experiments were analyzed and their requirements defined. A computer program was developed and used to define the observation methods and scheduling approach. This program accounts for orbital position, earth occlusion, sun position, time of year, and celestial coordinates of specific targets or areas of scan for mapping the celestial sphere.

The experiment requirements were compared with the capabilities of various mission/carrier configurations. Those considered were a separate mission for EMR only, a combination with ATM, an addition to the 1968 cluster replacing a planned flight, and as an additional flight to the cluster both with independent subsystems and by using available cluster subsystem support. Each configuration was analyzed and one chosen as being the most feasible.

The chosen configuration was analyzed in greater detail for overall compatibility. For every mismatch of existing capability versus new requirements, a solution was suggested either as new equipment, additions, or as modifications to the currently planned equipment, structures, or subsystems.

C. EO-0/LO-0

Experiment interface requirements for EO-0 and LO-0 experiment package integration on the LM&SS rack were determined and reuse/resupply problems of the EO-0 and LO-0 were studied. The EO-0 and LO-0 experiments are groups of experiments for the remote sensing of the earth and lunar surfaces, respectively.

It was concluded that a common LM&SS rack of experiments could be realized for earth orbit and lunar orbit vehicles. Variations in experiment lists may be desirable to enable the overall lunar mission to obtain complementary data between experiments. Both lists of experiments have common reuse problems.

Rack-mounted experiments are very difficult to resupply for reuse because of an astronaut's EVA limitations. It was concluded that the experiments may be reused if the experiments are extensively modified to facilitate resupply techniques and procedures.

The EVA aspects of EO-0 and LO-0 experiment packages were also studied to establish a concept that, if employed, could eliminate the EVA requirements of LO-0. On eliminating the EVA requirements, the experiments must still be amenable to resupply. This study was documented in ED-2002-62 and may be considered to be a continuation of ED-2002-46. For this report, it was concluded that it was possible to eliminate EVA requirements of LO-O experiments and replace them with IVA. This study also indicated that the multiple docking concept developed and illustrated in the report was the most promising method to achieve the desired objective. The decision was based on the advantages and disadvantages listed for various concepts discussed in the report.

Crew operations activities are divided into four major areas:

1) Crew systems integration - Determines the human engineering requirements for the design of equipment and systems that interface with the AAP flight crew;

2) Flight operations support - Determines the feasibility of proposed missions in terms of the crew's ability and the requirements for real-time mission support;

3) Crew safety - Conducts studies to determine the potential hazards due to systems design and operational requirements;

4) Crew training - Develops and establishes requirements of training and equipment needed to ready flight crews for each mission.

A. CREW SYSTEMS INTEGRATION

The crew systems integration involves human factors engineering, task analysis and simulation, and crew station development.

1. Human Factors Engineering - In the early part of Phase C, the primary system design inputs were design specifications for crew equipment and an identification of crew limitations and requirements, ED-2002-50. As the mission profile and flight hardware were more completely identified, the major inputs were made directly to the cognizant engineers at the drafting boards. Inputs that affected major design specification were formalized in crew equipment requirement forms and forwarded to P&VE Human Factors Engineering for review and implementation. In the final month of Phase C, all experiments listed for Flight 2 were included in reports (Human Engineering Considerations) that provide all current information about each experiment that is relevant to human engineering:

1) Summary of all human engineering considerations;
2) Time-line function and task analysis;
3) Illumination requirements;
4) Process analysis;
5) Safety considerations;
6) Simulation testing requirements;
7) Crew training requirements;
8) Crew support equipment considerations.

2. Task Analysis and Simulation - The data base for crew systems integration is provided by the analysis of crew activities. In parallel with the human factor engineering activities, the analytic methods and reports changed with the AAP requirements. Simulation analysis was required for critical tasks associated with making the S-IVB habitable.

Simulation of Man in Orbit - Many of the tasks to be performed during the activation of the Orbital Workshop were simulated to provide design development information. Figure IV-1 shows the Martin Marietta zero-g simulator in use. This facility consists of a six-degree-of-freedom moving base to which the subject is mounted. The test object is mounted by load cells that measure the forces imposed by the subject. The measurements are fed to computers, and the reactive forces are then transmitted to the servo motors on the simulator. All of the interreactive forces are recorded for analysis of the dynamics involved.

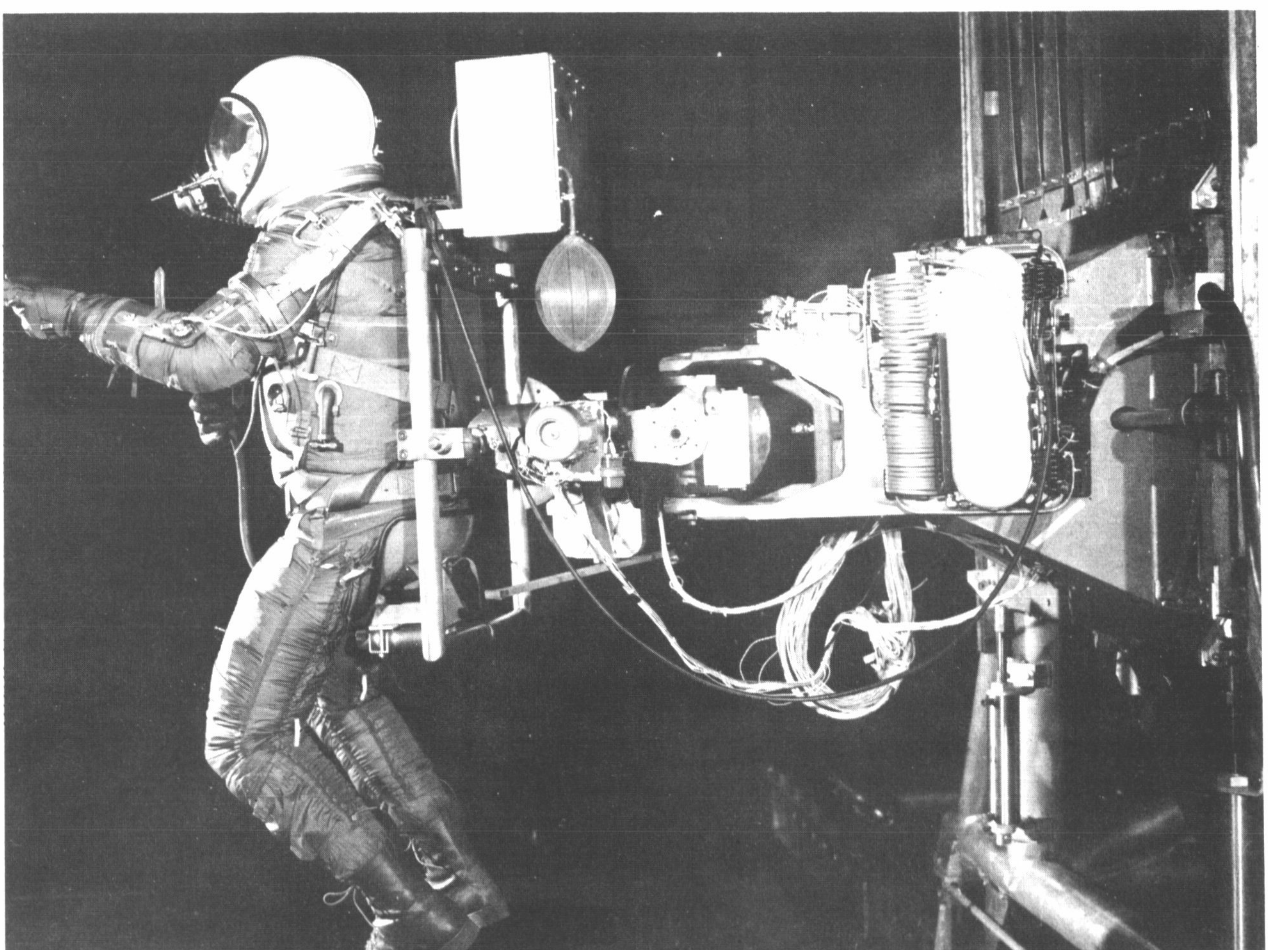


Figure IV-1 Martin Marietta Zero-G Simulator

Removal of Liquid Hydrogen Tank Manhole Cover - One of the first simulation efforts in Phase C was to determine whether a crewman could remove the 72 bolts in the liquid hydrogen tank manhole cover. Figure IV-2 shows a subject using the Martin Marietta zero-reaction hand tool to remove the bolts from a mock-up of the tank dome. This simulation supported the need for a redesigned cover providing a quick-release capability.

Full-Scale Mockup for Simulation - The full-scale mockup was used extensively in investigating the problems an astronaut will encounter during EVA. It was learned that each individual EVA must be carefully planned to determine the exact route to be taken and the proper handling of the umbilicals. Figure IV-3 shows a test subject on the ATM. The problem under study was the length of umbilical necessary to allow the crew to reach their destination.

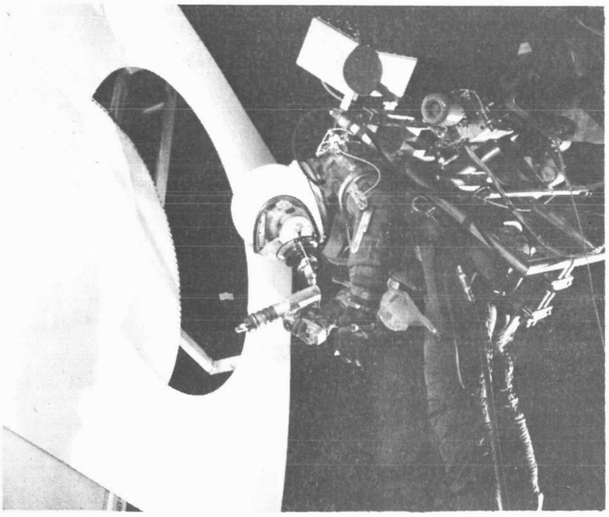


Figure IV-2 Zero-Reaction Hand Tool

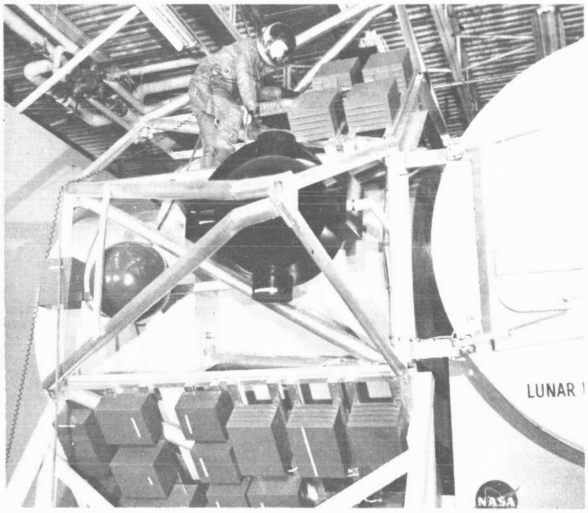


Figure IV-3 Test Subject on ATM Mockup

Transfer Aid Evaluation - An air-bearing platform was used to simulate different methods of transferring experiment packages and equipment from the MDA to the S-IVB. Figure IV-4 shows the proposed concept of using a pulley arrangement.

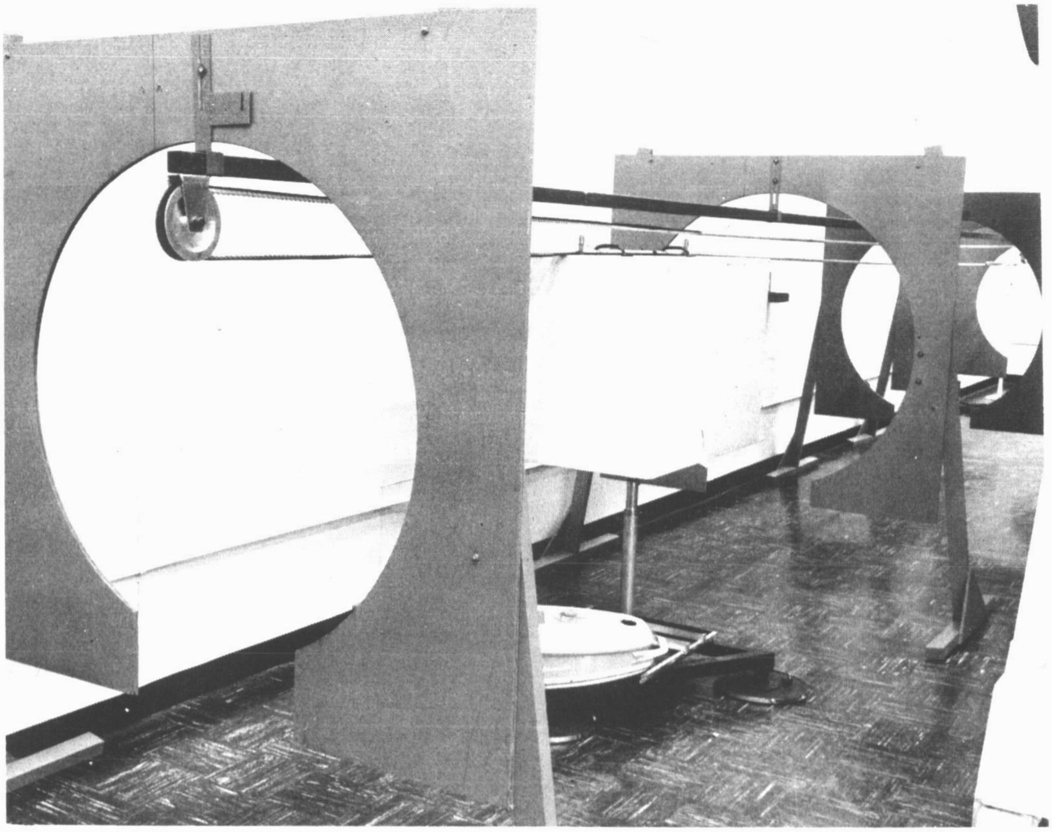


Figure IV-4 Pulley Arrangement for Equipment Package Transfer

Sealing Liquid Hydrogen Tank Chill Return Pump - Various methods to seal the liquid hydrogen chill return pump were investigated to determine the feasibility of technique as well as the magnitude of the tasks involved. The results of this study are discussed in ED-2002-54, Chill Pump Sealing Operation Simulation Report.

Sealing the S-IVB Liquid Hydrogen Tank Outlet - The simulation (see Fig. IV-5) showed that using a manual wrench to remove the 46 screws on the antivortex screen, is a laborious and unreasonable task for an astronaut to perform under the adverse conditions he will encounter. The use of power tools resulted in stripping the screw threads, thereby making it impossible for the astronaut to remove the screen.

Figure IV-5 Simulation of Sealing S-IVB Liquid Hydrogen Tank Outlet

The following recommendations are summarized from ED-2002-25, S-IVB Liquid Hydrogen Feedline Tank Outlet Sealing Operation:

1) Use a piano-type hinge on the straight side of the screen top;
2) Reduce the number of screws to less than 10;
3) Use larger screw with hexagonal heads;
4) Modify the level sensor brackets to provide tether attachment points;
5) Relocate the two sensors now over the screen.

<u>On-Orbit Simulation</u> - While the habitability task simulations were needed early in the program to determine flight feasibility, other simulations were required to provide quantitative data. The zero-g simulator was used to determine disturbance torques introduced by crew motions associated with routine activation such as arm movement, wall pushoff, and various types of walking. Figure IV-6 shows the zero-g simulator being used to measure the effects using Velcro to aid astronaut mobility.

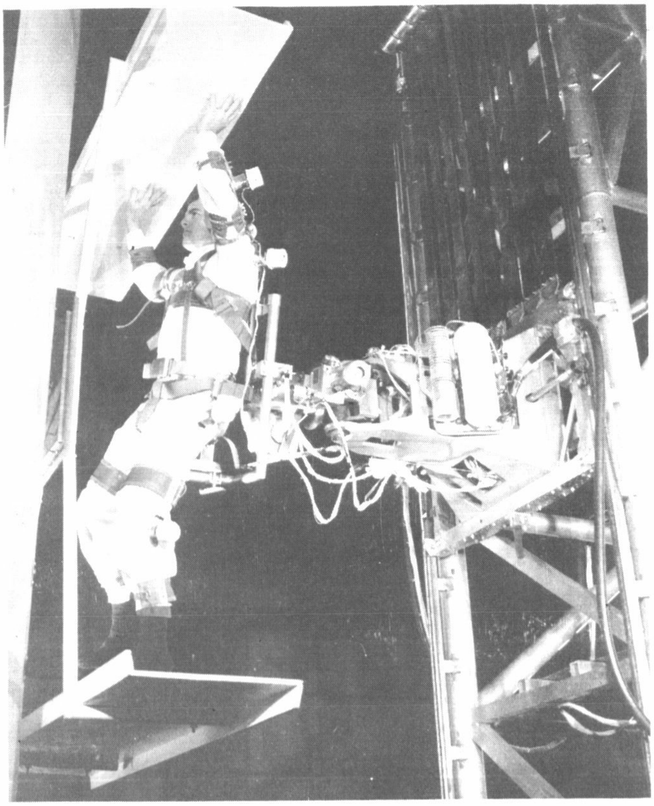


Figure IV-6 Zero-G Simulator

Task Analysis - Simulation provides data needed in the preparation of a task analysis. The analysis report is used to describe each crew activity, identify support equipment, note display and control requirements, estimate time required to perform an activity, and estimate workload. Three major accomplishments were achieved during Phase C:

1) A task analysis format and processing system was developed, which made crew information available to AAP. The list of 43 currently available task analyses is undergoing continuous extension, revision, and updating;

2) Tasks required in the habitation, closing, and reactivation of the workshop have been summarized in a complete package;

3) Experiment tasks and times have been presented in a form that permits scheduling of experiments in a preliminary flight plan. The feasibility of the payload integration plan is tested in this plan.

3. Crew Station Development

Crew Equipment Lists - As a byproduct of the task analysis, equipment required to support the crew was identified. The total amount of equipment estimated by this procedure included a number of items that were not identified by summing the equipment noted in the experiment report forms. Crew support equipment identification, equipment packaging, and efficient design of crew stations will be a major task in Phase D.

Results of our efforts in Phase C are contained in ED-2002-36, Crew Support Equipment Design Requirements. This report discussed:

1) Elimination of unjustified equipment redundancy;
2) Identification of support equipment for each experiment;
3) Definition of optimum storage and operating locations;
4) Design of hardware packaging schemes;
5) Identification of on-orbit material handling requirements.

Process Analysis - Thirteen process analyses have been completed wherein task and hardware flow patterns are superimposed on a drawing of the physical facility in which they are performed to:

1) Simplify the flow pattern;
2) Combine functional steps within tasks;
3) Eliminate unnecessary steps;
4) Determine whether a step could be better performed at another time or in another place.

Cluster Configuration - EVA Stations - EVA associated with the cluster has been a major concern. Task analyses of these activities indicated a number of problems that were studied using scale models of the cluster. Lighting problems and recommendations are discussed in ED-2002-87. Three methods of reducing glare at high contrast are considered:

1) Changing the orientation of the cluster so that the rays of the sunshine directly on the EVA area;
2) Conducting EVA on the dark side of the cluster and using artificial lights;
3) Using a screen to block sun glare and providing artificial lights.

Analysis and evaluation of EVA stations is continuing. Recommendations for umbilicals, restraints, and mobility aids are included in ED-2002-87.

Displays and Controls - The design of displays and controls for an integrated crew station within each vehicle was investigated from the standpoint of suitability of design, modular construction, panel layout, and ease of use. Evaluation of specific display and control problems within the CM resulted in an approach that would use externally stored, carry-on, modular-constructed, display packages.

The display and control concept developed would provide flexibility in satisfying program changes and reduce carrier interface problems to a minimum. The concept uses portable display and control units that can be carried by an astronaut to the required location. A single umbilical modification to all CMs for AAP is all that is necessary regardless of changes in experiment lists.

Figure IV-7 shows the portable display and controls that are required by the LM&SS experiments. Details of this concept are contained in ED-2002-86, Command Module Display and Control Requirements.

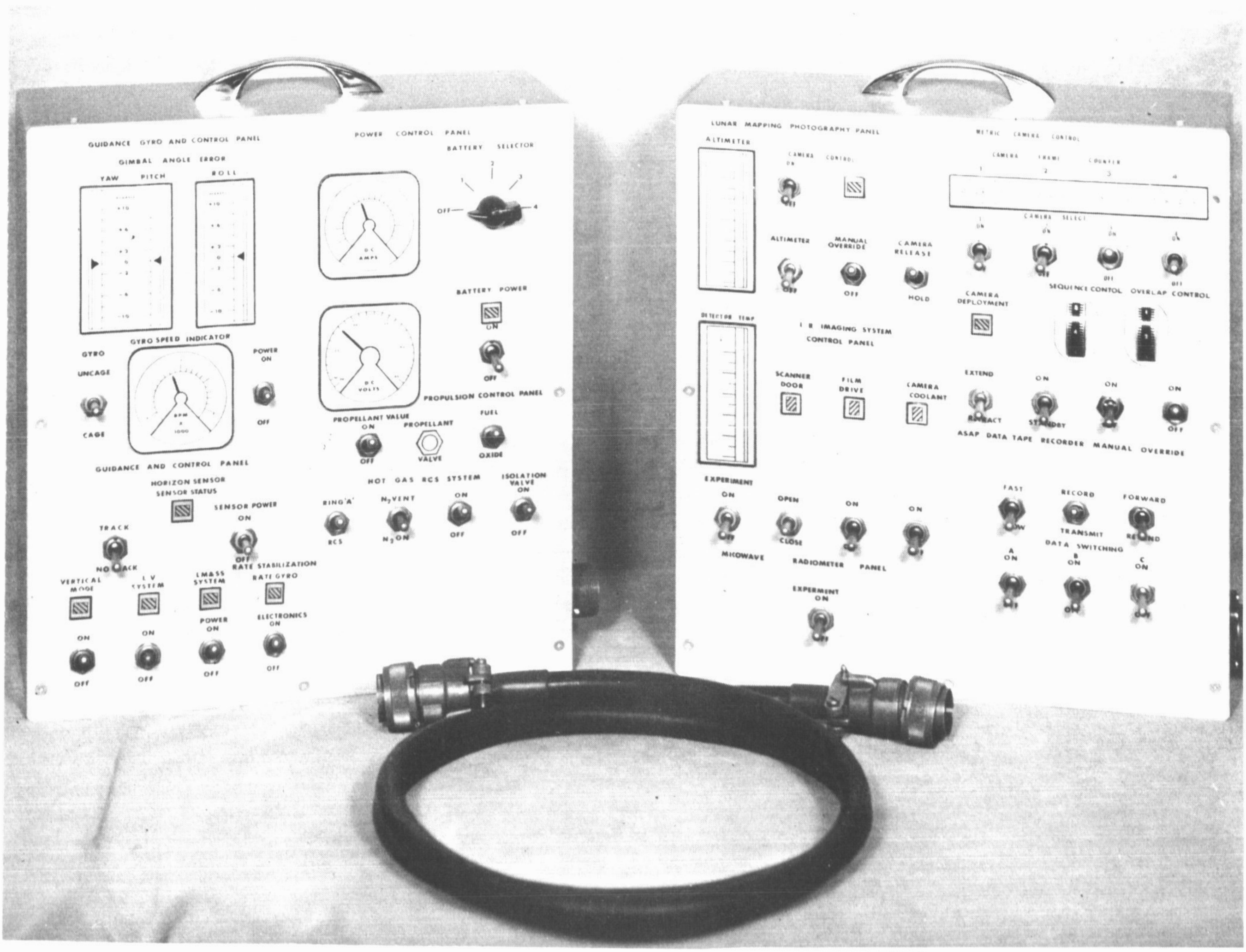


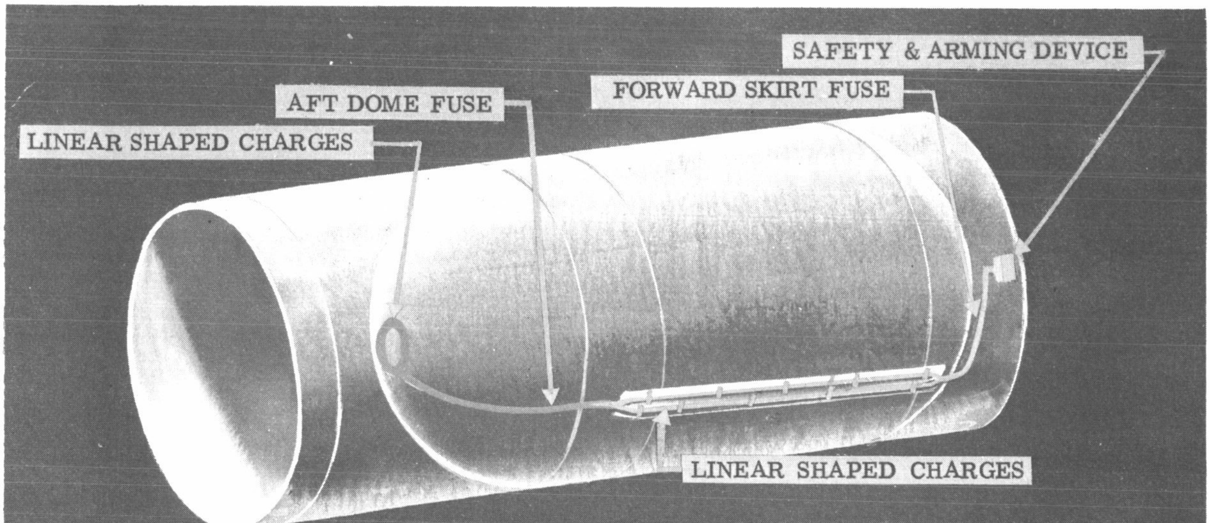
Figure IV-7 Portable Displays and Controls for LM&SS Experiments

B. CREW SAFETY

1. Crew Safety Summary - A mission-hazard analysis of Flight 2 indicated that several problems should be resolved before the safety of the crew can be assured. The major problems, discussed in detail in ED-2002-24, Crew Safety Analysis, are:

1) Flight termination system;
2) Radiation dosage;
3) Meteoroid penetration;
4) Polyurethane fire problem;
5) Command module deorbit alternative.

2. Flight Termination System - Figure IV-8 shows the simplified schematic of the S-IVB Flight Termination System. This system is safed electrically at the end of S-IVB powered flight by disconnecting the command decoder from its power supply. However, it remains mechanically armed in that the exploding bridge wires are left lined up with the explosive's trains.



PETN SENSITIVITY

TIME (SEC)	EXPLOSION TEMPERATURE
0.1	520°F
1.0	471°F
5.0	437°F
10.0	412°F
MELTS	255°F

EXPLOSIVE MASS (GRAMS)	RDX	PETN
S/A DEVICE		0.16
FORWARD SKIRT FUSE		100.4
LH_2 TANK CHARGES	386.4	10.4
AFT DOME FUSE		163.0
LOX TANK CHARGES	35.7	1.3
	422.1	284.26

Figure IV-8 S-IVB Flight Termination System

The total mass of explosives contained in the system is equal to approximately 2.5 pounds of TNT. Pentaerythritol-tetranitrate (PETN) becomes very sensitive at high temperatures. An analysis of the thermal profile of Flight 2 has shown that the outside skin of the S-IVB will reach 110°C when the rays of the sun are perpendicular to the skin. This will occur repeatedly throughout this mission. This system should be removed from the S-IVB for manned AAP missions.

3. Radiation Dosage - The displacement of the earth's magnetic poles from the geographic poles causes the Van Allen radiation belts to be displaced with respect to the earth's surface. This results in the belts being lowest over the South Atlantic, so that they generate what is referred to as the South Atlantic anomaly. The planned orbits for the low-earth orbit AAP missions will cause the spacecraft to pass through this anomaly. Analysis of this problem has identified the following.

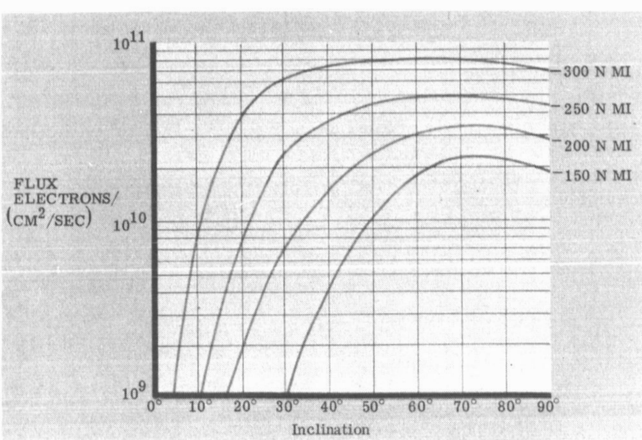


Figure IV-9 Flux Variation with Inclination and Altitude

Flux Variation with Inclination and Altitude - The time spent in the South Atlantic anomaly is obviously a function of both the orbit inclination and the altitude (Fig. IV-9), and thus the radiation dosage also becomes a function of these parameters. Figure IV-9 gives this variation in terms of electron flux. The area of low inclination provides a significant reduction in dosage but is unattractive from a mission standpoint since coverage of the earth is limited to an equatorial band. Orbital lifetime as a result of drag opposes the benefits of a low-altitude orbit.

Electron Flux Map at 300 Nautical Miles - Areas within the South Atlantic anomaly of constant electron flux are shown in Figure IV-10 for 10^4, 10^5, and 10^6 electrons per second. Orbital traces for an inclination of 30 degrees intersect these radiation areas periodically on slightly more than half the orbits. Radiation is accumulated on the basis of summing the time spent within the boundaries shown.

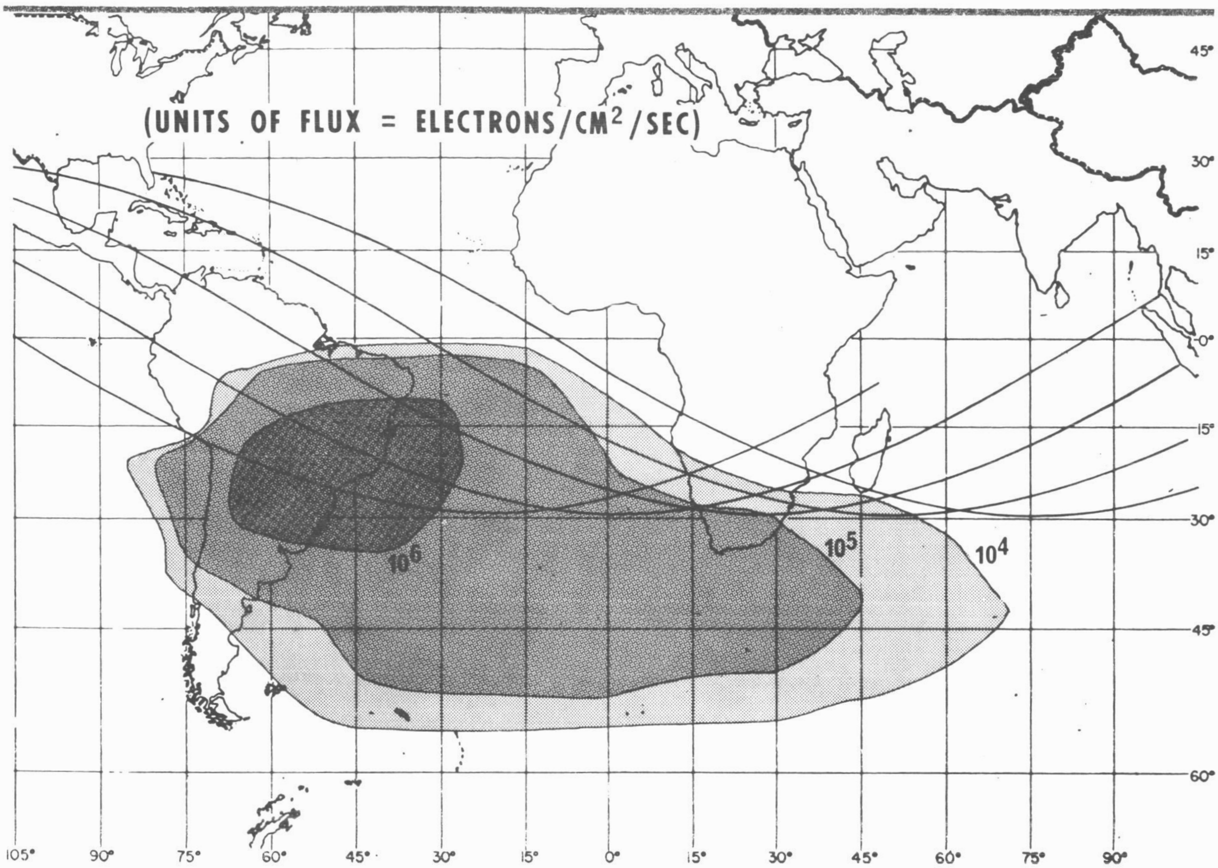


Figure IV-10 Electron Flux Map at 300 Nautical Miles

Typical Daily Flux History at 200 Nautical Miles, 50 Degrees - Figure IV-11 shows the radiation encountered as a function of time for a typical day. A period of approximately 10 hours is free of radiation and should be used for planning EVA. This variation with time is also a basis for planning the location of the crew within the cluster to minimize radiation dosage.

AAP Mission Radiation Exposure, 1968 - Analysis results available at present, are shown in Table IV-1. Radiation dosage levels are sufficiently high for low earth orbits at a 60-day duration to require detail analysis and possible planning of crew activities to minimize exposure. For mission durations of many months, protective measures are indicated.

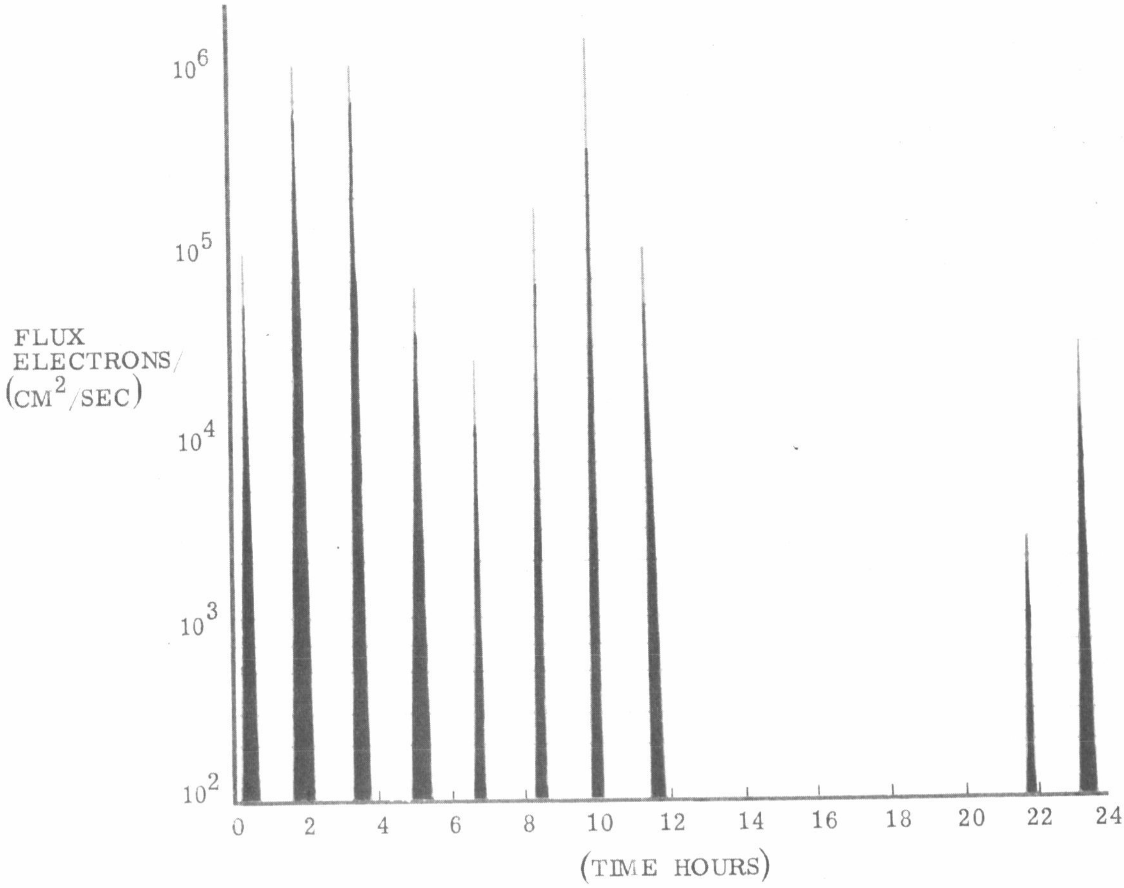


Figure IV-11 Typical Daily Flux History at 200 Nautical Miles, 50 Degrees

Table IV-1 AAP Mission Radiation Exposure

Altitude (n mi)	Inclination (deg)	Probability Flux is Less	Flux: Solar Flare (protons/cm^2)	Flux: Van Allen Belts (electron/cm^2/day)	Dose (rad/day): CM	Dose (rad/day): Lab
Lunar		0.995*	3.70×10^9*		400*	
Synchronous	0	0.995*	3.70×10^9*		400*	490*
		0.995		1.12×10^{13}	0.00008	0.028
200	30			7.8×10^9	0.012	0.034
200	50			2.45×10^{10}	0.038	1.07
260†	30			3.12×10^{10}	0.048	1.36

*For two weeks.
†EVA exposure to worst spike = 0.204 rad (20 minutes).

Effect of Location on Radiation Dose - As shown in Figure IV-12, radiation enters the OWS primarily thru the barrel of the tank where the protective material is minimum. The variation in the dosage is shown by a normalized curve as a function of station position. Crew quarters would encounter less exposure if located at the forward end of this workshop.

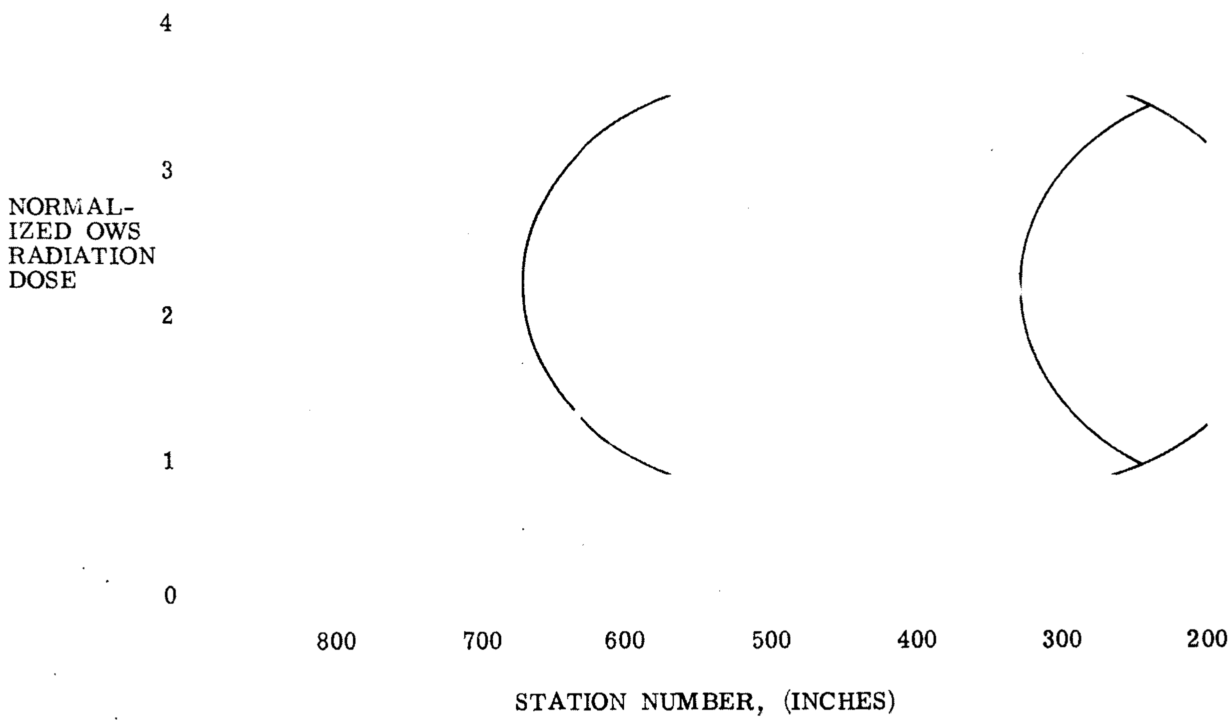


Figure IV-12 Effect of Location on Radiation Dose

OWS Dose as a Function of Added Protection - The curve of Figure IV-13 shows the benefit resulting from additional material added around the barrel position of the OWS. As an example, 1 lb/ft^2 is equivalent to the addition of a 0.064-inch thickness of aluminum, costing a total of 1800 pounds, and will reduce the dosage over much of the OWS volume by a factor of 80 percent.

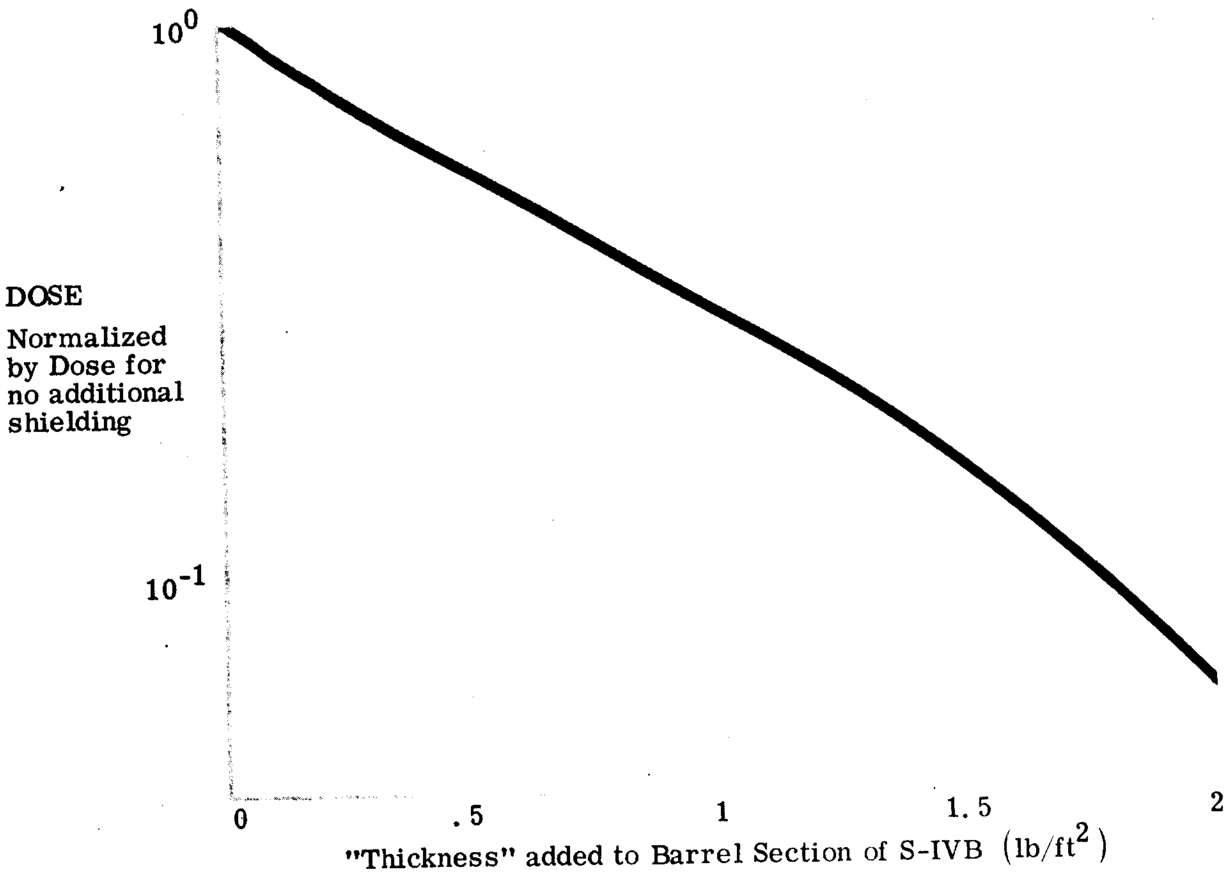


Figure IV-13 OWS Dose as Function of Added Protection

4. Meteoroid Penetration

S-IVB Venting Time vs Puncture Size - An uncontrolled loss of pressure in manned modules can result in serious consequences for the crew. The crew must be able to don pressure suits or reach a safe pressurized compartment before the onset of hypoxia. This occurs when the partial pressure of oxygen within the lungs drops below 60 mm Hg. Therefore, for the planned environment of the OWS, 70 percent oxygen and 30 percent nitrogen at 5.0 psia, the total pressure must remain above 4.1 psia.

Figure IV-14 shows the time required to vent the S-IVB liquid hydrogen tank from 5.0 to 4.1 psia, the critical life-support pressure through various size punctures. It has been estimated that it will require a crewman from five to seven minutes to evacuate the OWS to the CM. It can be concluded from Figure IV-14 that the critical size puncture is 0.83 inches in diameter.

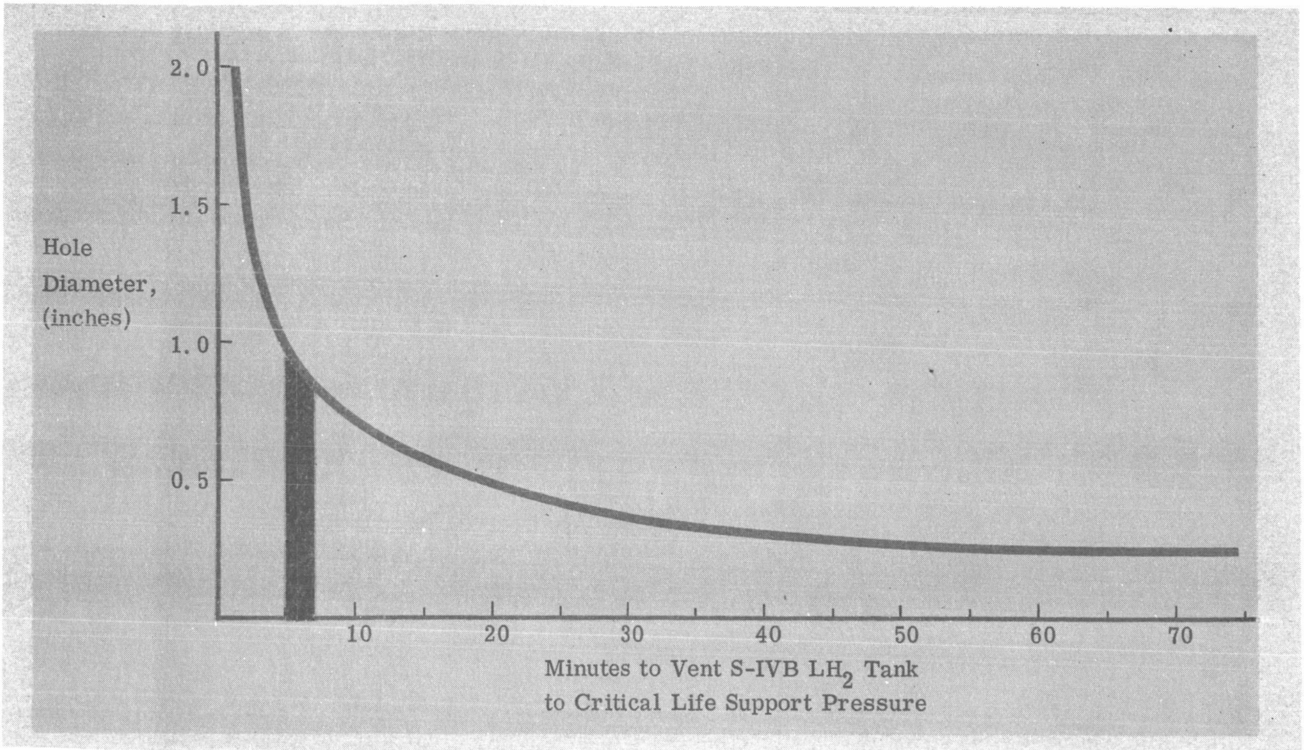


Figure IV-14 Puncture Size vs S-IVB Venting Time

<u>OWS Puncture Probability for 0.83-Inch Holes</u> - The puncture of the OWS by high-speed meteoroids is the most likely cause of loss of life-support pressure. Figure IV-15 shows the probability that all holes will be smaller than 0.83 inch in diameter, the critical diameter. This probability, as noted, is 0.9991 for 30 days, and 0.995 for one year. For these calculations, it was assumed that a meteoroid must pass through the metal tank wall, the polyurethane foam, and the fiberglas inner seal before pressure is lost.

<u>Effect of Bumper on Meteoroid Punctures</u> - Addition of material to the outside of the OWS increases the probability of no punctures due to meteoroid impact. Figure IV-16 shows that the addition of 0.010-inch aluminum will increase the probability of no punctures in 30 days to 0.9995 from 0.975 without a bumper.

To insure the availability of Flight 2 OWS for missions up to one year later, it will be necessary to add a bumper.

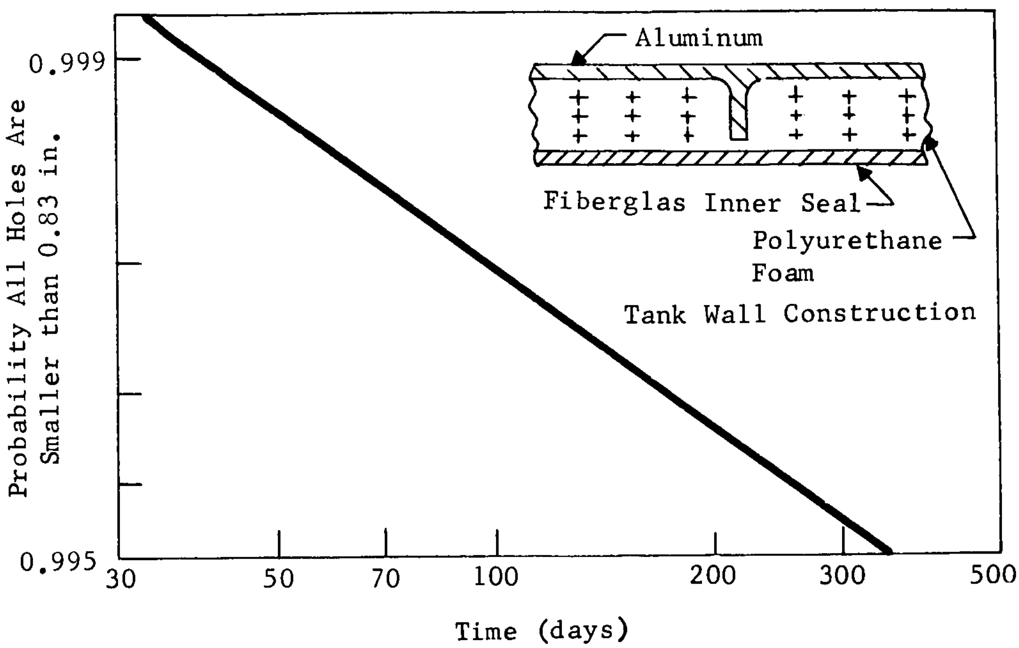


Figure IV-15 OWS Puncture Probability for 0.83-Inch Holes

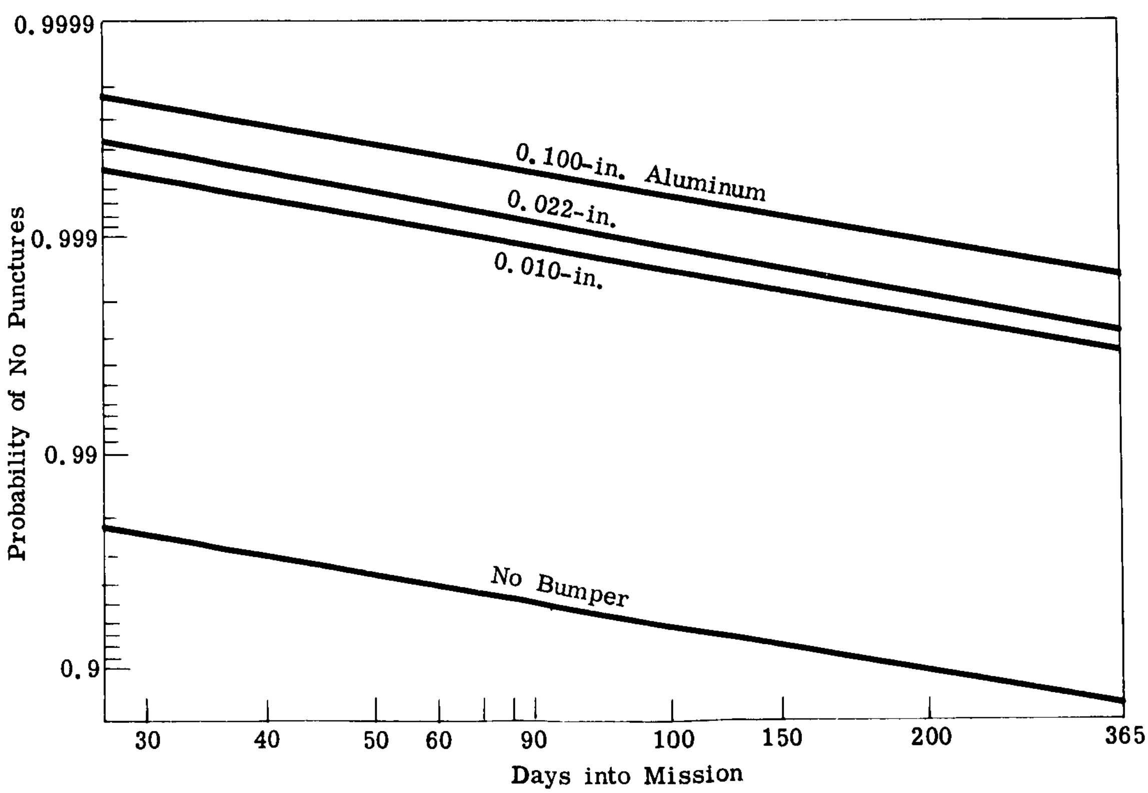


Figure IV-16 Effect of Bumper on Meteoroid Punctures

5. Polyurethane Fire Problem - The fire problem due to the polyurethane insulation of the liquid hydrogen tank has been subjected to intensive study by MSFC. Preliminary studies by Martin Marietta have indicated that the problem is not as serious as originally thought. The fiberglas liner will act as a barrier to the free flow of oxygen into the foam. Therefore, a fire in the foam must depend on the stored oxygen in the foam for sustaining the oxidation process. When the oxygen in the foam has been depleted, less than 1 percent of the polyurethane will have been consumed. Inability of the combustion byproducts to dissipate will aid in extinguishing the fire.

Table IV-2 RCS Deorbit

Initial Altitude (n mi)	Velocity Decrease to Deorbit (fps)	RCS Propellant (lb)
100	270	740
150	230	630
200	290	770
250	360	990
300	440	1205

6. Command Module Deorbit Alternative - The only alternative means to deorbit the CM in the event of a malfunction of the SM SPS is to use the SM-RCS. The amount of RCS propellant required to affect a deorbit from various altitudes (assuming a circular orbit) is shown in Table IV-2. At present, the SM carries approximately 1285 pounds of propellant, and almost all of it will be used for attitude maneuvers. It is obvious that during Flight 2 the crew will not have an alternative capability to deorbit from the 270-nautical-mile altitude.

The most effective backup means to deorbit is the use of strap-on solid motors as used in the Gemini and Mercury programs. Such a backup system would add approximately 1000 pounds to the CSM.

C. FLIGHT OPERATIONS SUPPORT

1. Summary of Activities - The flight operations portion of crew operations activity was devoted primarily to determining the feasibility of each proposed mission considering the crew ability to fly the mission and to conduct experiments. Additional effort was expended in the study of mission support requirements for all AAP missions.

Various time-lines were developed in an attempt to satisfy the demands of the anticipated experiment workload and effort was devoted to working with experiment analysis to combine experiments where practicable.

Crew constraints and requirements were developed for input to design reference mission documents. This information was contained in a preliminary report, ED-2002-50, Crew Operations Requirements for Combined Cluster Mission.

Each maneuver required to complete a mission was studied to determine its feasibility. The more obvious problems are associated with the docking of the experiment carriers to the MDA to form the cluster configuration.

2. Basic Crew Schedule - A joint meeting of representatives from NASA Headquarters, MSC, MSFC, and Martin Marietta was held to develop a basic crew schedule to be used by all agencies in experiment/carrier study and development. The following ground rules were used to develop the basic crew schedule:

1) The crewman on watch must be in the CM at all times. He may sleep or may assist in experiments;
2) Briefing for watch responsibility exchange is assumed to be covered during meal periods;
3) EVA preparation time is assumed to be 2 hours.

3. Docking Problem Studies

Docking LM&SS to MDA, First Method - The first proposed method of docking the LM&SS to the MDA is illustrated in Figure IV-17. An analysis of this method indicated that the CSM would have to be rolled approximately 7.5 degrees clockwise for the command pilot to be able to see the standoff cross docking aid through the rack structure. It was apparent that this maneuver would be most difficult to complete.

Docking LM&SS to MDA, Second Method - The second proposed method of docking the LM&SS to the MDA called for the CSM to switch ends during flight to dock the forward end of the LM&SS to the MDA. As the first proposed technique, the CSM must be rolled about 7.5 degrees clockwise to clear the command pilot's line of vision.

Change of CSM Docking Positions, LM&SS - The second proposed method of docking required that the CSM change from one end of the LM&SS to the other, before final docking to the MDA. This maneuver is shown in Figure IV-18.

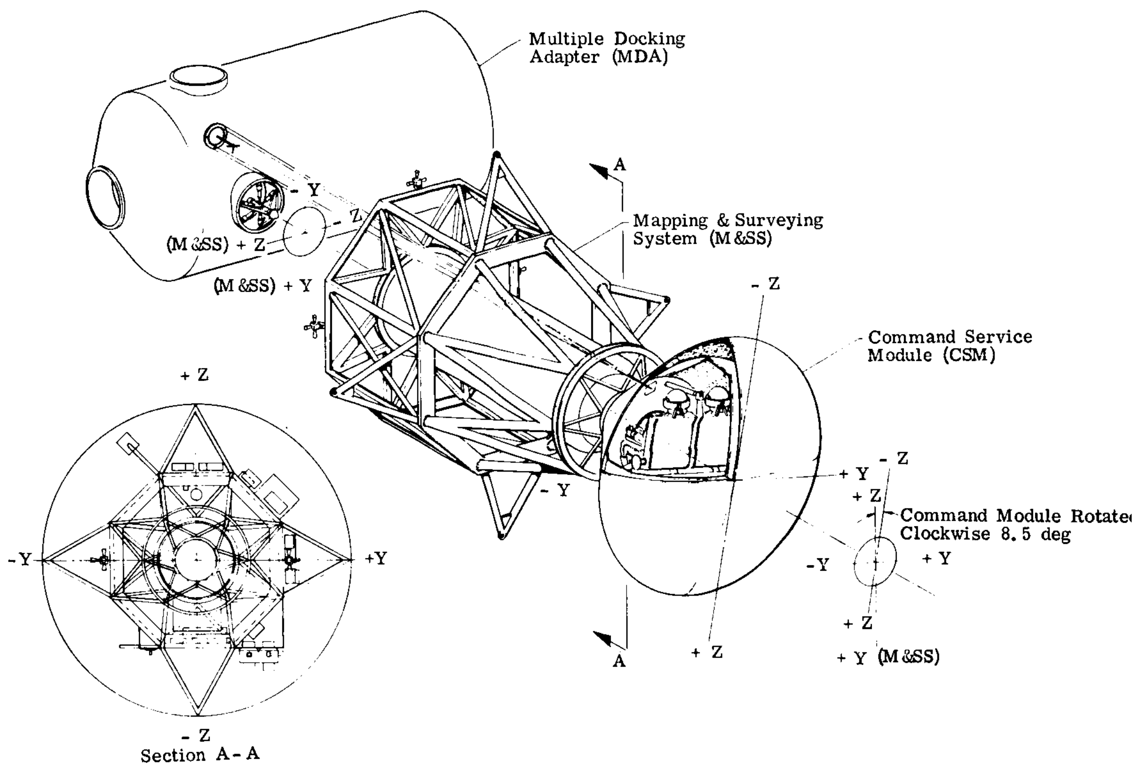


Figure IV-17 Docking LM&SS to MDA, First Method

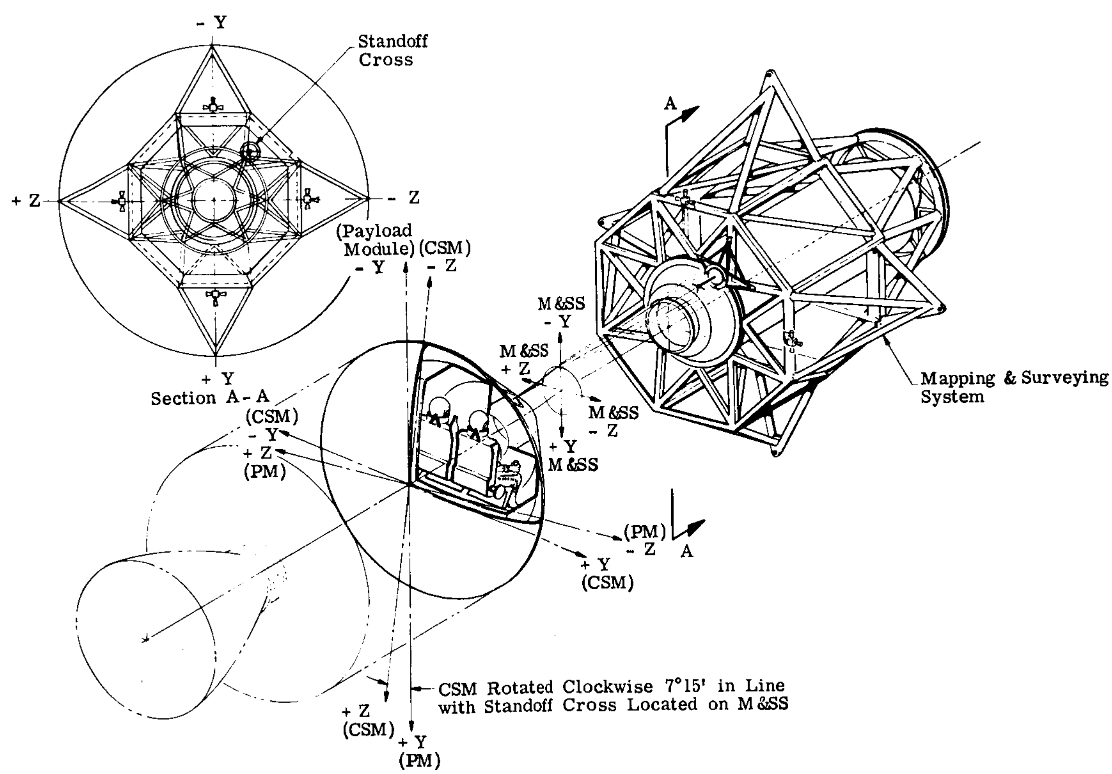


Figure IV-18 Change of CSM Docking Positions

If the standard technique of using a standoff cross as a docking aid is required for alignment of the two vehicles, it was learned that this maneuver must be accomplished by the senior pilot from the right-hand couch. This is necessary since a standoff cross located on the LM&SS for use by the command pilot would block his view during final docking to the MDA. This maneuver required the addition of an independent stabilization system on the LM&SS.

Docking LM&SS Without Rack Structure - Leaving the rack structure attached to the S-IVB would provide good vision to the crew during docking of the LM&SS to the MDA. This maneuver is shown in Figure IV-19. This method is preferable to the earlier proposed methods.

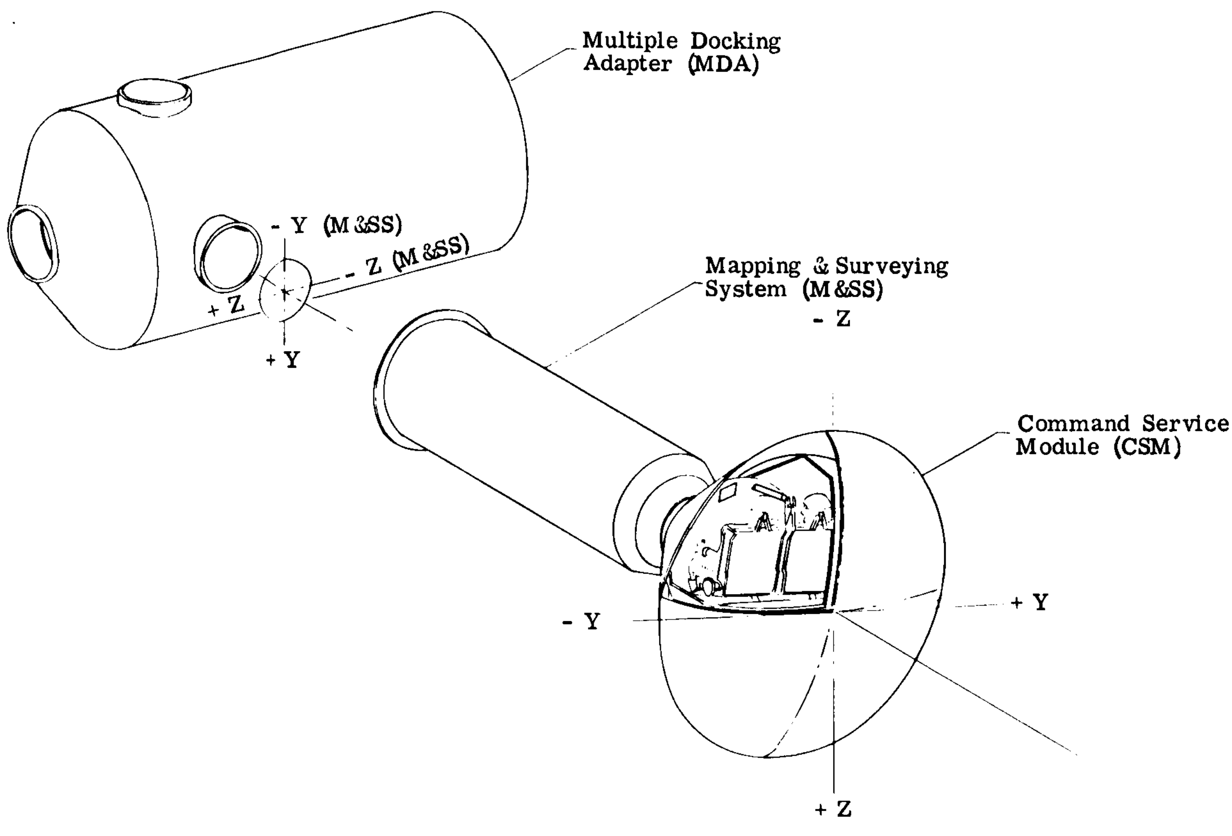


Figure IV-19 Docking LM&SS without Rack Structure

Resupply Module Docking - The maneuvers required to dock the RM to the MDA were studied and led to the proposed alignment shown in Figure IV-20. By rolling the CSM 14 degrees counterclockwise before docking to the RM, the command pilot would have good visual access to a standoff cross docking aid on the MDA for final docking. This maneuver would have to be accomplished from the right-hand couch.

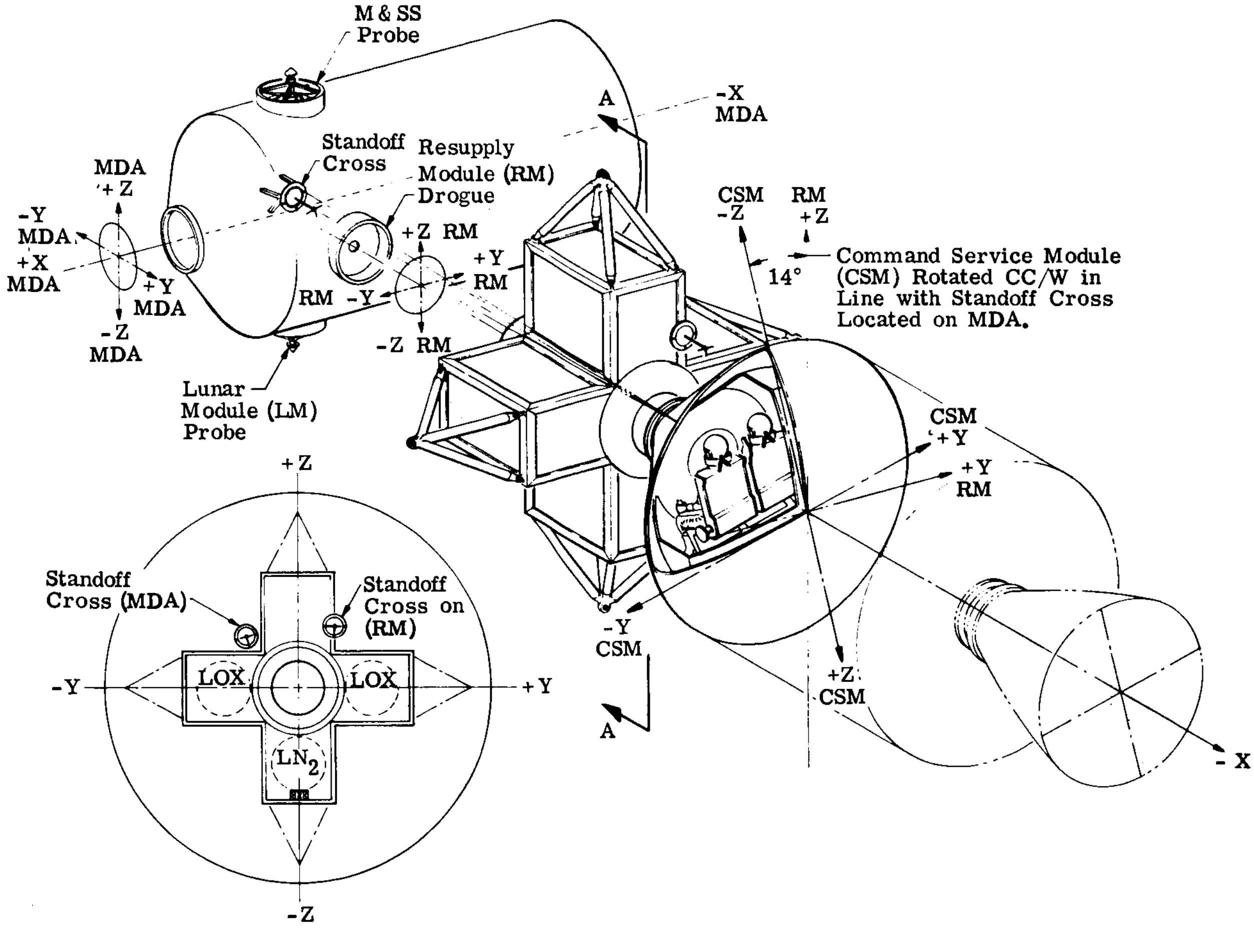


Figure IV-20 Resupply Module Docking

4. Mission Operations Support - The requirements for mission operations support (see Fig. IV-21) for AAP missions were studied. Four mission support functions were identified and the activity within each was examined as well as its relationship to the total mission operations organization.

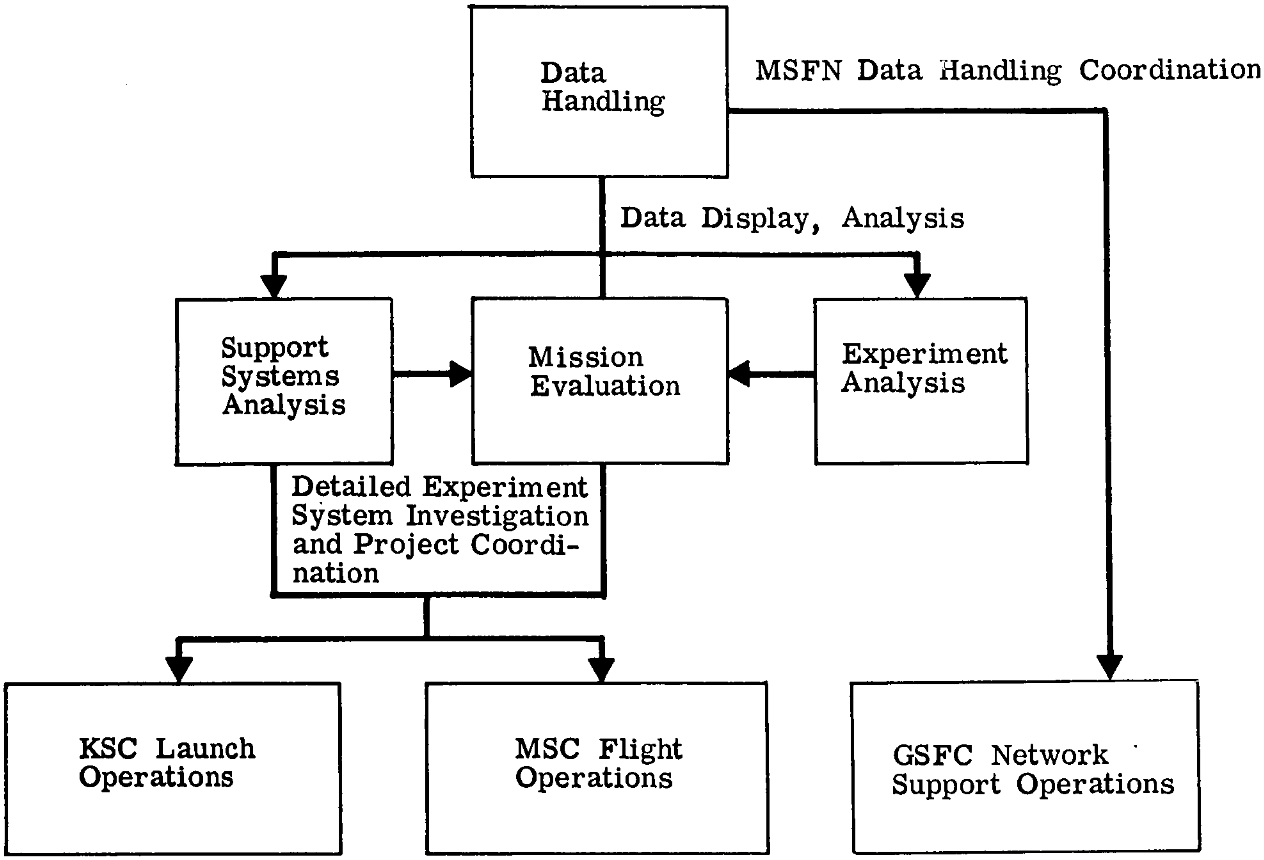


Figure IV-21 Mission Operations Support

The data handling function integrates the experiment data requirements and coordinates their implementation. During the mission period it coordinates MSFN requirements with GSFC network support team. The support systems analysis function provides detailed experiment system data and assists in detailed technical investigation of problem areas during the mission.

The experiment analysis function performs quick-look analysis and makes recommendations on procedures and equipment use to maximize scientific returns on experiments.

The mission evaluation function provides technical support for detailed mission definition and support planning. It also maintains mission status and evaluates experiment technical performance in terms of program objectives.

D. CREW TRAINING REQUIREMENTS ANALYSIS

1. Detailed Experiment Training Requirements Analysis - Training requirements for each item of experiment hardware associated with each particular experiment were identified to delineate the in-flight crew task requirements for the transfer setup and operation of each hardware item.

2. Training Requirements Summary - An analysis of the AAP experiments and associated operations was conducted to identify the type and level of training required to assure crew safety and maximum proficiency of performance.

3. Training Time Allocation Sheets - Table IV-3 shows the results of an analysis to determine the total time required to train an astronaut for Flight AAP-2 regular activities. It was determined that a total of 57 days is required.

Table IV-3 Required Training, Flight AAP-2

Flight AAP-2 / Experiments and Operations	M487 Crew Quarters/Habitability	D019 Suit Donning & Sleep Station Evaluation	D018 Integrated Maintenance	M050 Metabolic Cost of Space Flight Tasks	M052 Bone and Muscle Changes	M051 Cardiovascular Function	M053 Human Vestibular Functions	M054 Neurological Study	M018 Vectorcardiogram	D020 Alternative Restraints	D012 Astronaut Maneuvering Unit	M466 Spacesuit & Lunar Hardware Evaluation	M486 Astronaut EVA	D021 Expandable Airlock Technology	T020 Jet Shoes	M469 ST-124 Removal & Disassembly	M489 Heat Exchanger Service	M488 High-Pressure Gas Expulsion	D022 Expandible Structure for Recovery	M479 Zero-g Flammability	M493 Electron Beam Welding	T017 Meteoroid Impact & Erosion	T021 Meteoroid Velocity	M492 Tube Joining in Space	M464 Onboard Checkout Equipment	T003 In-Flight Nephelometer	XXXX Radiation Monitor	S009 Primary Cosmic Radiation	S017 X-Ray Astronomy	T013 Crew-Vehicle Disturbance	T023 Surface Adsorbed Materials	M055 Time and Motion Study	Passivation, Activation or Deactivation of S-IVB OWS	Activation or Deactivation of Airlock Module	Multiple Docking Adapter	Training Time (days)
Systems Training	Note: All times presented here are in hours.																																			
S-IVB Workshop	6																																6			2
Airlock Module																																		6		1
Multiple Docking Adapter																																			6	1
Experiment and Experiment Carrier Test Participation	3		1								1	6		3		3			2			2														3-3/6
Experiment Operations	3	1	3	2	2	2	2	1	1		3	3	3	1	3	3	2	1	2	2	2	1	1	2	2	2										8-2/6
Operations Training																																				
Experiment-Peculiar Guidance Procedures																																				
Crew Stations and Storage Reviews with Experiment Carrier	3	1	3	2	2	2	1	1	1	1	2		3	1	2		1	1	2	1	1			1	1	1	1	2	1	1	1					6-4/6
Apollo Mission Simulation																																				
Part Task - Experiments	2	2	3	2	2	2	1	1	1	1	2	2	2				1	1	1		1		2	1	2	1										5-5/6
Mission Task - Experiment & Carrier	2									2			2				1	1								2					2					2
Integrated Mission	2		5								2		1				1	1							2	2										2-5/6
Extravehicular Activities & Zero-Gravity Tasks	9	3	15				2			2	8	7	25	5	9	6		1	5	2	3			2	3			1			1	12		18		24
Total Days																																				57

4. Flight Crew Training Implementation Schedule - The effort to train a crew for a flight must begin 16 months before the launch date. Figure IV-22 shows the time span for the individual training activities.

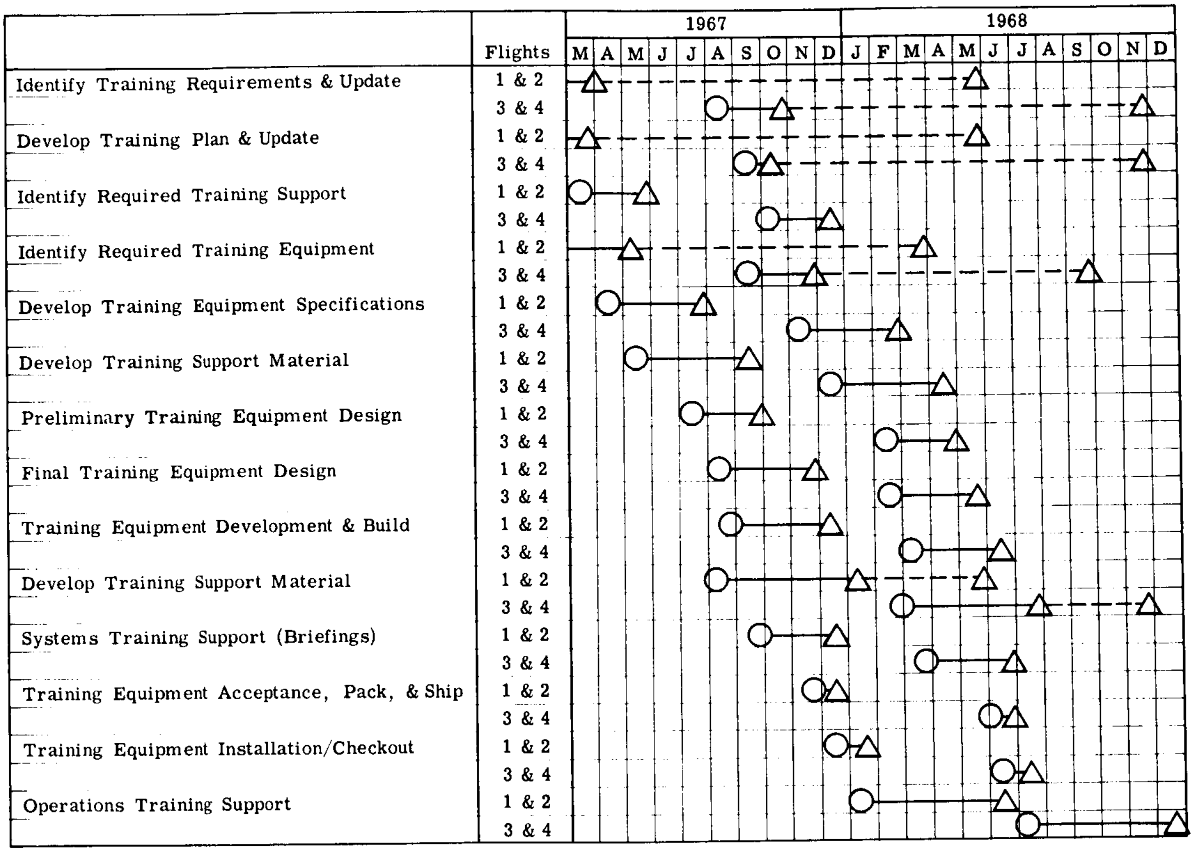


Figure IV-22 AAP Training Implementation Milestones

5. Training Equipment - AAP experiment operations will require flight crew personnel to perform a significant number of crew translations in and around the cluster configuration. The techniques for IVA and EVA movement will require the training of flight crews in a simulated environment to understand in-flight conditions. Some experiments will require precise control of the cluster and various segments of the cluster in performance of rendezvous, docking, and target acquisition pointing and tracking. Some experiment items will require training equipment to provide

the flight crews with proficiency training in setting up experiment equipment, initiating experiment sequences, as well as deactivating, tearing down, and storing experiment hardware and data samples.

Training equipment items required to support AAP imposed activities are delineated in the flight crew report, ED-2002-40, submitted to MSFC on March 31, 1967, and in Addenda A and B of the Design and Development Plan, PL 2055, submitted to MSFC on April 7, 1967.

A. FACILITIES

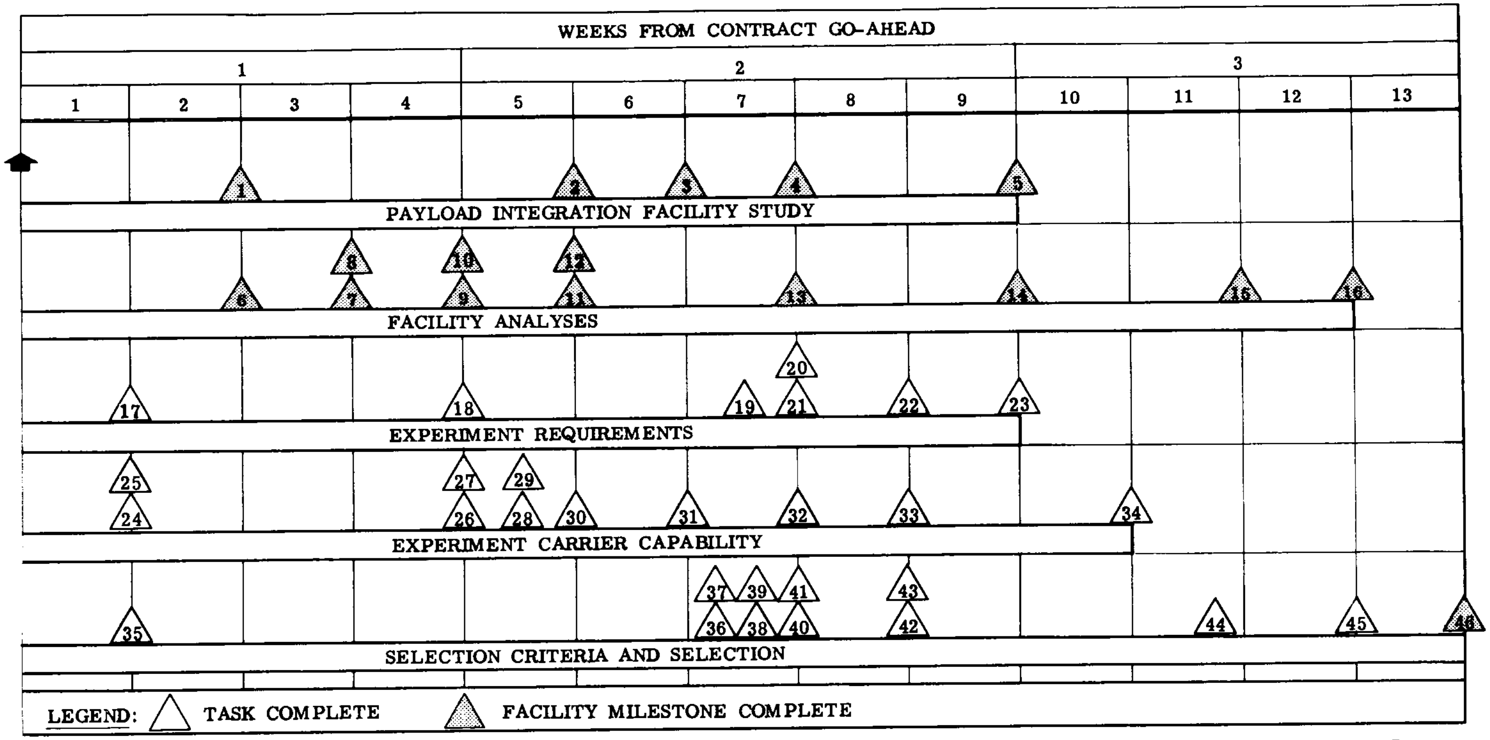
Facility activities during Phase C were directed toward three primary objectives -- (1) develop tradeoff studies to assist MSFC in determining the most desirable payload integration facility location; (2) provide MSFC with early identification and definition of facility requirements and problems associated with the development, integration, and launch of AAP flight hardware for which MSFC is responsible; and (3) preparation of the general facility plan for incorporation in the Phase D AAP proposal.

1. Initial Three Months - During July, August, and September of 1966, effort was focused on establishing Denver AAP Phase C study facilities and preparing the preliminary facility investigation study.

a. Denver AAP Phase C Study Facilities - AAP engineering and administrative operations were consolidated into a newly furnished project area in the Denver Administration Building in July of 1966. A new AAP mockup area was constructed and activated in the Denver Inventory Building in September of 1966.

b. Preliminary Facility Investigation Study - The preliminary facility investigation study (ED-2002-1) was completed in September and submitted to MSFC in early October 1966. This study contained the preliminary definition of requirements for overall AAP payload integration facilities, with a comparison of existing facilities and capabilities at MSFC, KSC, and Martin Marietta (Denver) candidate locations. A comparative study of the effects of each location on overall program operations and NASA and contractor program costs was also conducted. MSFC was found to be the most advantageous location for the payload integration facility from both an operational and cost basis. The major differential resulted from management control problems, which were found to be greater when the payload integration facility was geographically separated from MSFC. Figure V-1 indicates the major facility milestones (shaded) that were completed in preparing the preliminary facility investigation study.

2. Intermediate Six-Month Period - Facility effort during the period of October 1966 thru March of 1967 has been directed toward (1) detailed analysis of facility requirements, capabilities, and additional facility needs to specifically support AAP Flights 2 and 4 at MSFC and KSC; (2) field surveys and coordination meetings at MSFC and KSC; (3) planning of facilities to be provided by the contractors at Huntsville, Alabama, and (4) preparation of the general facility plan for incorporation in the technical operations plan submitted as part of the Phase D proposal.



GLOSSARY OF MILESTONES:

Contract Go-Ahead

1. Develop Payload Integration Facility Parameters
2. Evaluate Location Effects on Management Visibility & Control
3. Evaluate Facility Location Effects on Manpower
4. Evaluate Location Effects on Program Schedules
5. Evaluate Location Effects on Costs
6. Review Facility Description Documents
7. On-Site Survey of Existing Government Facilities
8. Determine General Technical Facility Requirements
9. Evaluate Contractor Facility Capability
10. Determine Government Facility Capability
11. Evaluate Contractor Facility Availability
12. Determine Government Facility Availability
13. Determine Facility Deficiencies & Problems
14. Define Initial Facility Requirements
15. Technical Facility Requirements Analysis
16. Facility Investigation Results
17. Experiment Data Analysis
18. Determine Experiment Grouping
19. Experiment Requirements for Manned Operation
20. Experiment Requirements for Unmanned Operation
21. Experiment Requirements for Reactivation
22. Experiment Support System Requirements Envelope
23. GSE, Test, & Facility Requirements for Experiment
24. Mission Definitions & Objectives
25. Experiment Carriers To Be Considered
26. Low Earth Orbit Mission Performance Requirements
27. Synchronous Orbit Mission Performance Requirements
28. Lunar Orbit Mission Performance Requirements
29. Lunar Landing Mission Performance Requirements
30. Exclude Obviously Inappropriate Carriers
31. Establish Capability of Each Carrier (Manned)
32. Establish Capability of Each Carrier (Unmanned)
33. Establish Capability of Each Carrier (for Reactivation)
34. Evaluate Modifications of Each Carrier
35. Establish Initial Selection Matrix Elements
36. Determine Criteria for Carrier Selection
37. Cost Considerations
38. Development Risk Considerations
39. Schedule & Availability Considerations
40. Crew & Training Considerations
41. Spacecraft GSE, Test, & Facility Considerations
42. Identify Additional Criteria
43. Establish Selection Matrix
44. Perform Tradeoff Studies for Each Matrix Element
45. Carrier Selection Recommendation
46. Deliverable Reports

Figure V-1 Program Milestones (First Three Months)

a. Facility Planning for Flights AAP-2 and AAP-4 - The initial AAP-2 and -4 facility effort focused on the preparation of first- and second-level hardware flow plans through MSFC and KSC; the identification of facility requirements on a functional basis at MSFC, KSC, and other locations; and field surveys to determine the adequacy or inadequacy of existing facilities to satisfy the identified functional requirements. Supporting tradeoff studies, organization analyses, and detailed task plans were also completed as required to support this planning effort.

The AAP-2 and -4 facility plans were prepared for the primary purpose of providing MSFC with early identification and definition of facility requirements associated with the development, integration, checkout, and launch of these specific flights. Requirements needed to support all identifiable AAP primary program functions, including receiving and inspection, experiment accommodations, fabrication, assembly and installation, test, development, technical support, launch, mission support, and general and administrative support operations at MSFC, KSC, contractor plants, and other locations, were considered.

The results of this planning effort indicated that, with the exception of required contractor-furnished facilities off-site at Huntsville, existing facilities at MSFC, KSC, contractor plants, and other locations can be rapidly activated with minor additions and modifications to support Flights AAP-2 and -4. For detailed consideration of facilities, see the Flight S/AA-2 Facility Plan (PL 2016), January 30, 1967, and AAP-4 Facility Plan (ED-2002-70), March 24, 1967, which were delivered to MSFC during February and March of 1967, respectively.

b. Field Surveys and Coordination Meetings - During the six-month period, a substantial facility field survey and coordination effort was conducted at MSFC. Periodic task efforts were complemented on a day-to-day basis by a facility representative who was located at MSFC on a full-time basis. Surveys and coordination with MSFC personnel were performed to acquire detailed data and drawings for existing and planned MSFC facilities; review facility reports and documentation; and discuss MSFC philosophy, organization, funding policies, procedures, and guidelines required for the preparation of Phase C facility plans and the facility portion of the Phase D proposal. The MSFC property accountability system was reviewed and a presentation made to MSFC on the Denver thermal vacuum chamber and the rendezvous and docking simulator.

Field activity at KSC during the period consisted of the acquisition and verification of facility data on existing facilities at MILA; review of TRW plans and projected AAP facility requirements and utilization plans; review of our facility documentation and test plans; discussion of philosophy, organization, procedures, responsibilities, and guidelines for preparation and implementation of AAP facility requirements at KSC; and familiarization of Martin Marietta personnel with MILA facilities.

c. Contractor Facilities - Preliminary requirements, criteria, and schedules for the provisioning of Martin Marietta and Bendix off-site Huntsville facilities were also developed. Available property at Huntsville was surveyed during January of 1967 to establish the locations and availability of desirable property. Our present plan for providing contractor facilities is set forth in detail in PL 2056, Technical Operations Plan, which is a part of the Phase D proposal.

d. Preparation of General Facility Plan - Recent effort has been directed toward the preparation of a general facility plan, including a Denver/MSFC payload integration facility alternative effects study and AAP Flight-2 and -4 addendums, which has been included in the Phase D proposal.

B. LOGISTICS

In October 1966, we published a preliminary study that indicated in-flight maintenance should be considered on missions extending beyond 14 days. Tradeoffs related to factors involving redundancy, reliability, maintenance support, criticality of the system, and complexity of the tasks should be conducted to determine whether maintenance support will be carried aboard the spacecraft. A follow-on study (ED-2002-85) was completed on April 7, 1967. The final study indicated that in-flight maintenance tasks are required for the present basic Apollo program and the presently defined AAP missions, and should definitely be considered for future long-duration missions.

Maintainability criteria were developed for both ground and in-flight maintenance of AAP experiments, support subsystem carrier add-on modules, and GSE. These criteria are necessarily quite general but can be used as guidelines by AAP contractors not familiar with aerospace techniques. MSFC received these criteria in the preliminary DRMD for Flight 2.

Logistic concepts and policies for AAP were developed early in the period and then coordinated with our MSFC counterparts in meetings on November 16 and 17. Changes and additions recommended by MSFC were then incorporated. These concepts were the basis for our AAP logistic planning and the Phase D proposal inputs. In addition, a preliminary logistics support plan was prepared that covered in some detail our proposed method for supporting AAP and integrating the logistic activities of the various contractors involved in the payload integration tasks. This plan will be delivered as a technical report and covers the following support elements: maintainability, maintenance, material support, operations and maintenance instructions, transportation, contractor training, and base services.

During the Phase C study program we have analyzed the elements that we consider to be critical in the achievement of a successful quality, reliability, and test program. As a result of this analysis, we have determined that special emphasis must be applied to certain activities if program goals are to be met.

Some of the areas are:

1) Quality, reliability, and test programs for experiments;
2) Failure mode, effect, and criticality analyses;
3) Identification and solution of single-point failures;
4) Failure reporting and corrective action;
5) Integrated testing of experiments, carriers, and spacecraft;
6) Special quality techniques for assembly operations;
7) Systems safety program to protect hardware and people;
8) A quality system that can react to changing program requirements.

The quality, reliability, and test program we have developed considers these special requirements as well as those specified by NPC 200-2, NPC 250-1, and NPC 500-10.

A. QUALITY ASSURANCE

Quality assurance activities completed during Phase C AAP are summarized as follows:

1) Defined quality assurance technical facility requirements;
2) Monitored, inspected, and recorded received GFE (LM mockup);
3) Established ground rules for control of experiment developers in conjunction with MSFC reliability and quality assurance (R&QA);
4) Presented R&QA program approach to MSFC;
5) Prepared second-level breakdowns from master functional analysis charts and developed functional flow diagrams for assigned mission AAP 209, Flight 2;

6) Initiated safety and quality assurance requirements for payload development;

7) Prepared quality plan for PL 2056, Technical Operations Plan;

8) Prepared quality assurance task definitions and technical requirements for assigned missions;

9) Prepared detailed task breakdowns of quality assurance and systems safety activities for cost proposal;

10) Prepared systems safety plan.

1. Quality Assurance Program - During the Phase C study program we determined that an AAP R&QA manual was essential for conducting the AAP.

The program requirements were studied and evaluated to determine the quality requirements needed. An outline paralleling the requirements of NASA quality and reliability documents NPC 200-2 and NPC 250-1 was prepared (Fig. VI-1).

The quality manuals of the Martin Marietta and Bendix corporations were reviewed and analyzed to determine the policies, practices, and procedures currently in use that could be applied to the AAP. This effort made use of procedures already established in other NASA programs and that conform to NASA quality requirements. Further definition was accomplished to establish additional requirements specifically applicable to AAP.

The manual outline was tailored for this purpose. As an example, standard inspection practices will be continued at receiving inspection, but additional requirements were recognized as essential since many of the AAP articles will be one-of-a-kind, contracted by various NASA centers, and received from sources remote from MSFC. Controls to be imposed by Martin Marietta are individually tailored to meet these contingencies.

Results of further program analysis determined that the R&QA manual must impose special disciplines in certain areas to meet AAP goals. Those areas were identified as:

1) Failure analysis and corrective action;

2) Control of integration activities.

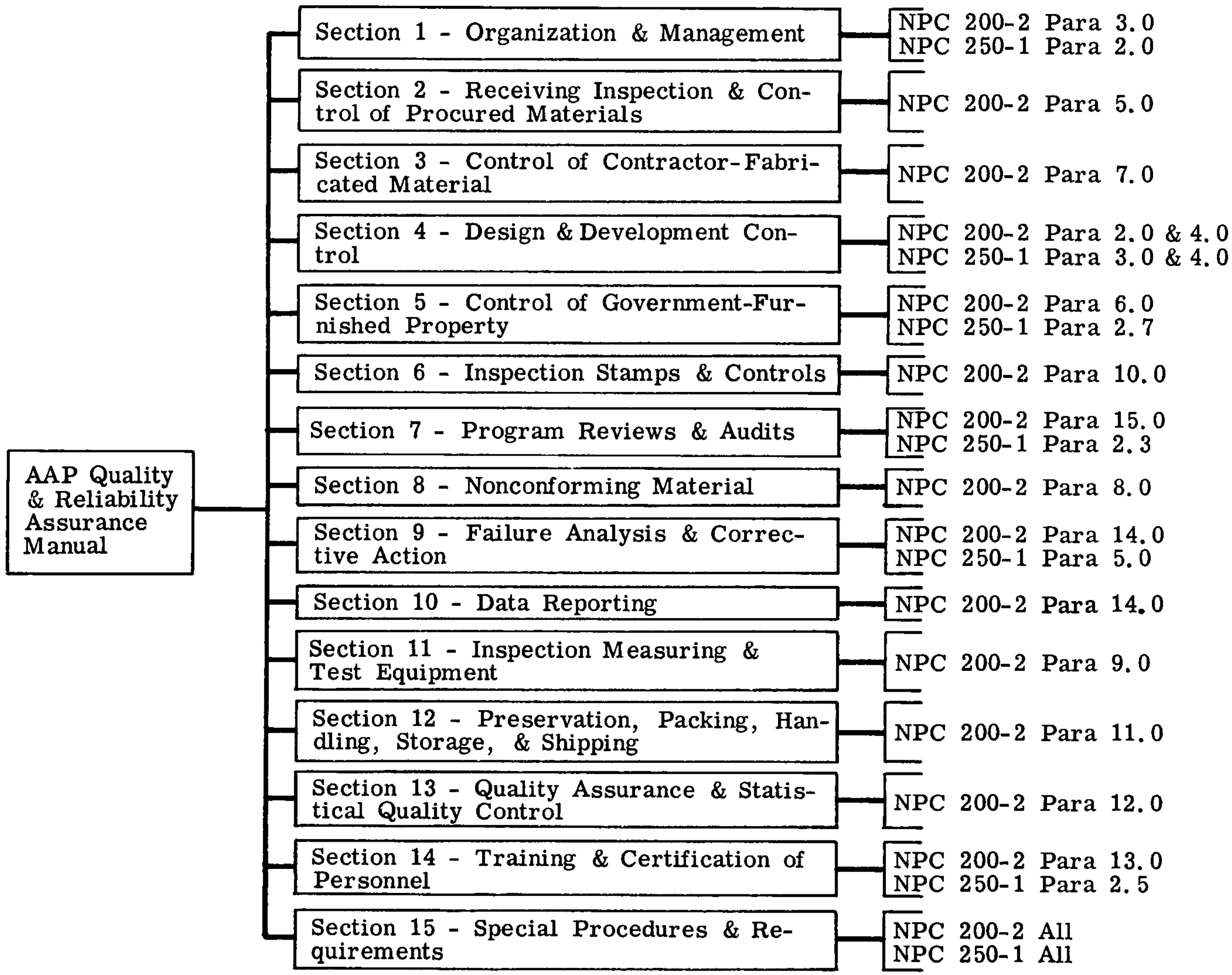


Figure VI-1 Outline for R&QA Manual

An analysis of the requirements for AAP failure reporting and corrective action was conducted. The manual will provide for a Corrective Action Control Center (CACC) patterned after a similar operation in the Gemini and Titan programs. This center provides for immediate reporting and rapid response to hardware, software, or flight anomalies. It was determined that this type of action was essential to AAP due to the one-of-a-kind type and complexity of AAP hardware. Studies performed indicated that corrective action will occur under normal conditions, but in the AAP, expediting problem solutions is of primary importance. The CACC will fulfill this obligation. The CACC operation is shown in Figure VI-2.

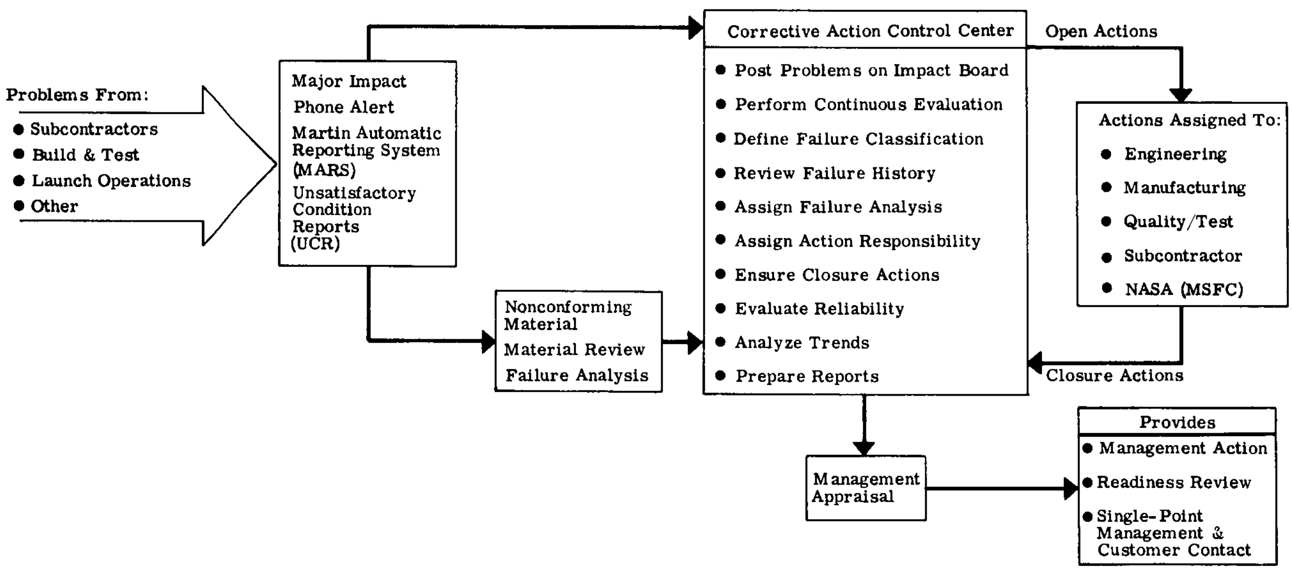


Figure VI-2 Corrective Action Control Center Operation

In controlling the integration activities, it was determined during the Phase C studies that positive cleanliness controls will be required throughout the integration cycle. The added demands for cleanliness by biomedical experiments and carriers was recognized. To meet these requirements, the R&QA manual will impose controls during the integration cycle. Modules, experiments, carriers, and systems susceptible to adverse contamination will be placed in limited access and controlled areas. Accountability will be maintained for tools, paper, materials, etc to guard against foreign material appearing in flight hardware. It was determined that random rotation and low-level vibration will also be used to detect incorrect assembly techniques or the presence of foreign material.

The quality assurance program that we developed during the Phase C study provides for the special requirements discussed as well as the requirements of NPC 200-2 and are incorporated in the R&QA manual.

2. Quality Assurance Program Plan - During the Phase C study we developed and submitted an AAP quality assurance plan, which was included in PL 2056, Technical Operations Plan. The quality assurance plan described the controls to be implemented by the R&QA manual at the payload integration facility and also included recommendations to MSFC. These recommendations included methods for standardizing quality assurance provisions for experiment contractors. Phase C studies indicated that criticality levels (FMECA established by Reliability for each experiment) could be used as the basis for establishing standardized quality requirements. Criticality Categories I and IIA would require a quality or inspection plan based on NPC 200-2 or 200-3. Other criticality categories would require individual requirements based on the degree of criticality. All requirements would be included in the interface control documents and subsequent work statements to contractors.

We also concluded that assistance could be provided to MSFC in controlling experimenters after the quality requirements have been established. R&QA working groups will be available to assist MSFC in conducting design reviews to ensure that the quality requirements have been included. These personnel will also assist in audits of experiment developers, reviews of quality and inspection plans, and witnessing acceptance tests. It was concluded that this latter function will serve to minimize further testing after receipt. The quality requirements flow for experimenters is shown in Figure VI-3.

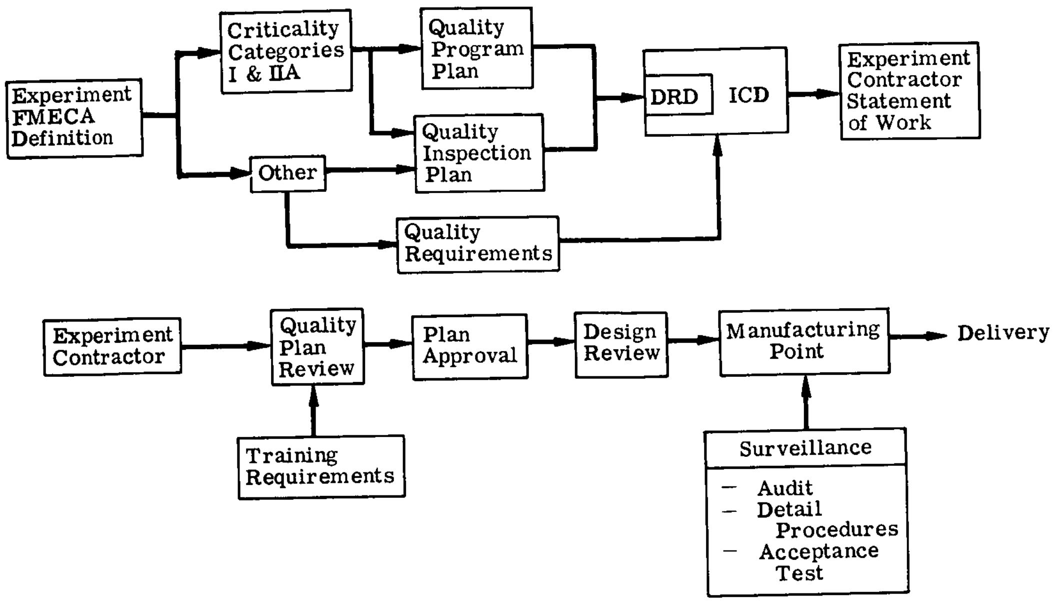


Figure VI-3 Quality Requirements Flow for Experiments

3. Systems Safety - During the Phase C study we recognized that special emphasis must be placed on identifying and solving safety problems involving design, production, and operations of entire AAP systems. To ensure that the systems safety requirements are properly implemented in the AAP, our analysis indicated the need for a safety requirements and procedures manual patterned after the Martin Marietta Safety Manual, M-64-125. This manual establishes the safety engineering principles applied throughout the design engineering, fabrication, test, installation, and checkout of hardware.

The system safety program plan we have developed (ref Design and Development Plan, PL 2055) for AAP provides for design analysis to identify hazards that may be inherent in the design. Functional flows for identifying critical safety areas requiring safety analysis must be developed. Similar operational analyses of procedures, equipment, and test methods must be performed to develop requirements for emergency procedures, backout procedures, and safety requirements needed in test procedures. These analyses identify the need for training and certiciation of personnel

In performing design and operational analyses we intend to obtain a safety analysis from interfacing contractors. Such reliability information as failure modes and equipment are used for design and operational analysis.

To effect proper communications and provide guidance on all matters dealing with systems safety, we have determined the necessity for a systems safety working group consisting of members from the various technical disciplines. Other contractors interfacing with hardware for which Martin Marietta is responsible must also be represented. These working group members ensure proper continuity of implementation of system safety requirements and procedures. They will also be responsible for coordinating, reporting, and taking corrective action on assigned problems.

Periodic reviews with MSFC safety personnel are recommended to facilitate information exchange, review safety activities, and determine problem status. Systems Safety must also conduct audits to ensure that practices, procedures, and policies are being followed.

Milestones for conducting the AAP systems safety program are shown in Figure VI-4.

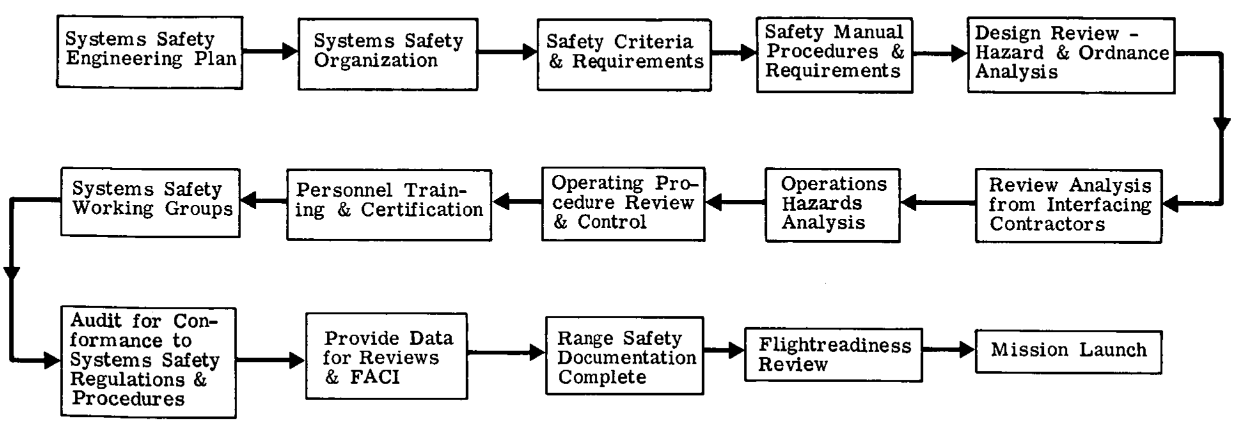


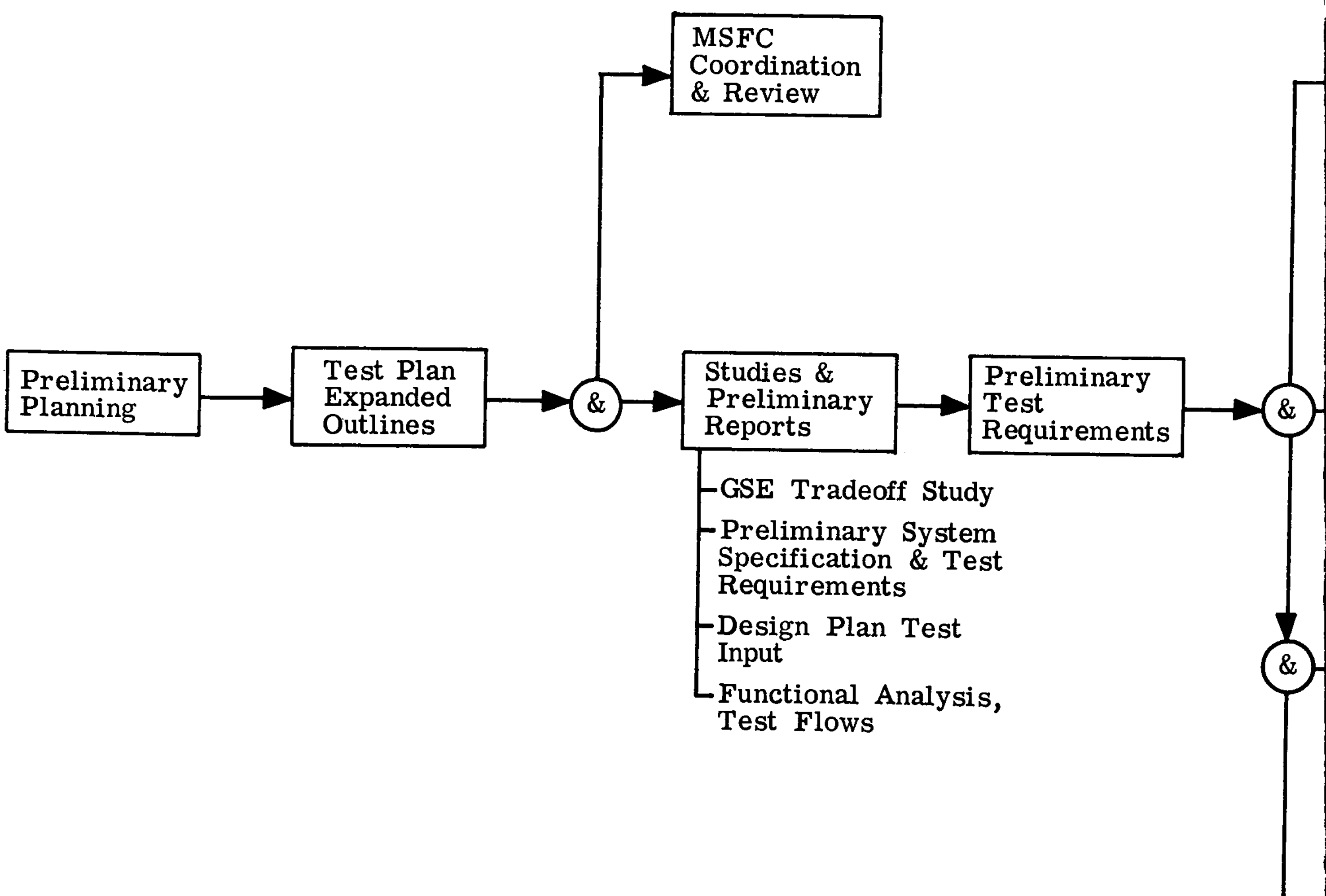
Figure VI-4 Systems Safety Milestones

B. TEST ENGINEERING AND OPERATIONS

This report presents a summary of the test engineering and operations activities for Phase C of the Apollo Applications Program. All aspects of the test program from development testing of components through integrated system tests of the flight spacecraft modules were explored. The primary task was the preparation of test plans covering the major test activities, with emphasis on AAP Missions 1/2, 3/4. In support of this task, several special studies were made that yielded detailed information for such critical tests as the cluster design verification tests. As a result of test planning activities, it was possible to identify the major GSE, special test equipment, and facilities required to support the tests identified. The control and management of the test program was also investigated. In performing the above tasks, we coordinated our efforts with MSFC and KSC.

Subsequent sections of this report present brief summaries of the work accomplished during this reporting period along with our recommendations for future test activities in both planning and operations areas.

1. Activities Summary - Test activities occurring between July 1966 and April 7, 1967, are summarized in Figure VI-5. The first half of this period was mainly devoted to exploring the gross details of the test program as guided by the test plan outlines that were initially prepared and coordinated with MSFC. The initial goal was to establish basic test requirements for MSFC-responsible hardware configurations. As sytems design solidified during the last portion of this study, the details of the test program for Flights 2 and 4 were increasingly emphasized. In addition to the Phase C study tasks, concentrated Phase D proposal effort was initiated during February. Final reports and the proposal documents were submitted April 7, 1967.


Preliminary Planning
Test Plan Expanded Outlines
&
MSFC Coordination & Review
Studies & Preliminary Reports
GSE Tradeoff Study
Preliminary System Specification & Test Requirements
Design Plan Test Input
Functional Analysis, Test Flows
Preliminary Test Requirements
&
&

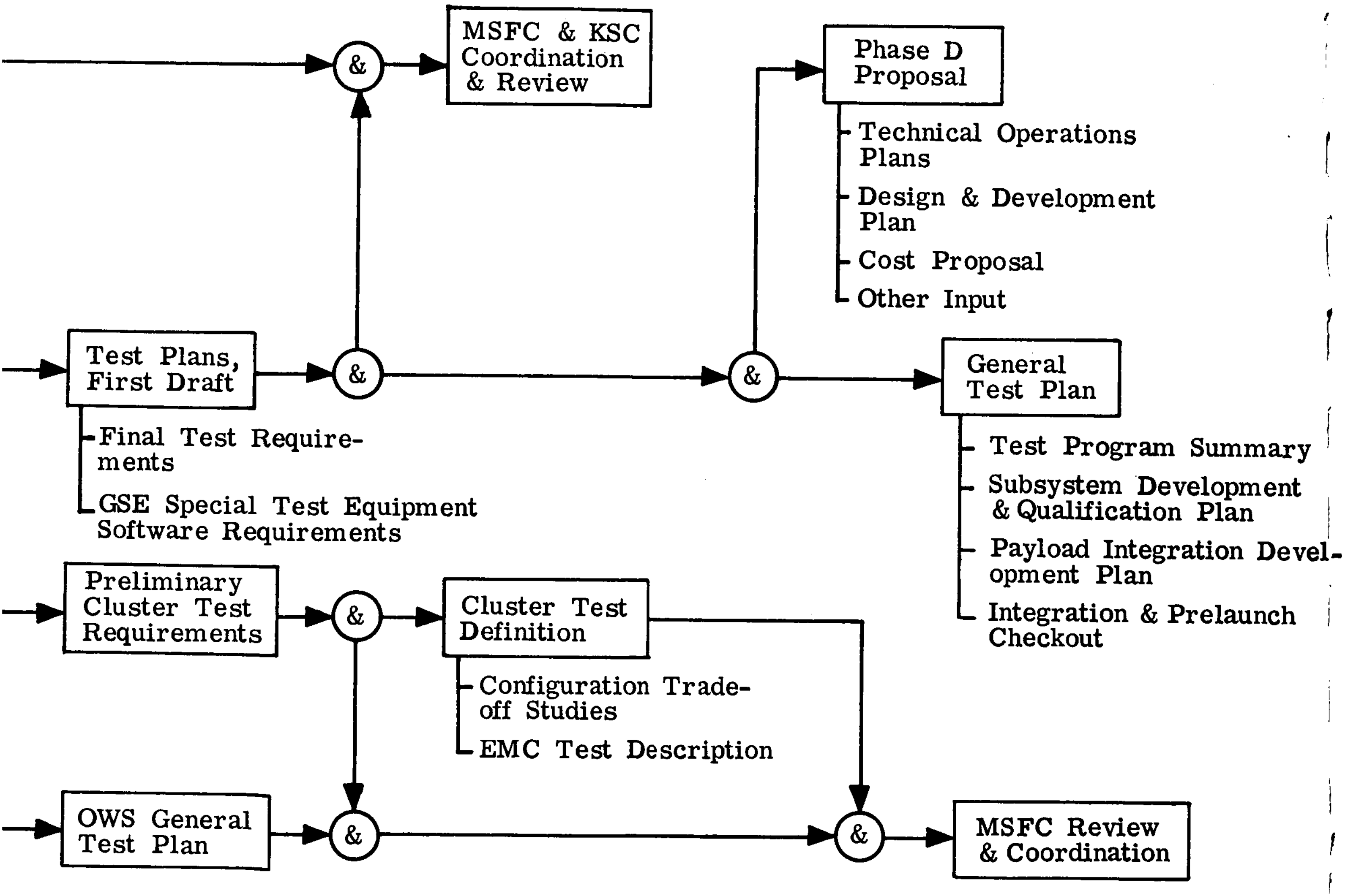


Figure VI-5 Test Activities Summary Chart

2. Preliminary Test Planning Activities - A product of the first three-month portion of Phase C was the payload integration test plan. From this document and the test plan outlines developed early in Phase C, our efforts were devoted to establishing the basic test flows to which the AAP experiment modules would be subjected. Matrices were simultaneously developed that depicted the types of environmental and functional test requirements for each applicable experiment module in the Missions 1/2, 3/4 configuration. Figure VI-6 shows samples of test flows and matrices produced during this time. This type of basic information was used to derive imputs to such other documents as facility requirements, the preliminary quality assurance section in the general specification for Missions 1/2, 3/4, and inputs to the design reference mission document (DRMD). Considerable effort was also expended in the preparation of test tasks for AAP-2. These included fourth-level tasks associated with all aspects of the AAP-2 test program from test plan preparation to writing final test reports. Other activities in which the Test Engineering and Operations Section participated were:

1) Preparation of the test input for the preliminary Phase D statement of work;
2) Assisting the Design Engineering Section in identifying GSE that would be required to support the test program;
3) Revising and expanding the test flow and test plan outlines;
4) Performing analyses of the potential effects that the late arrival of experiments at KSC might have on test operations.

The preliminary planning activities described above culminated in the publication of the preliminary test requirements document. It detailed the specific environmental and functional test requirements for each experiment module and flight and orbital spacecraft configurations. An analysis of the requirements imposed by the orbital-configured cluster indicated that many design verification requirements could best be satisfied by ground testing the spacecraft in the orbital configuration. Likewise, it became apparent that the flight hardware would have to undergo a comprehensive test program to confirm proper performance of the cluster. These and other tests such as thermal vacuum testing of the OWS and ATM/rack, the ATM experiment angular alignment tests, and pointing control subsystem verification emerged as the major test tasks to be pursued during the remainder of this phase. It was also determined that minimal emphasis should be placed on defining detailed tests for components and subsystems since only meager information of the depth required would be available in the immediate future.

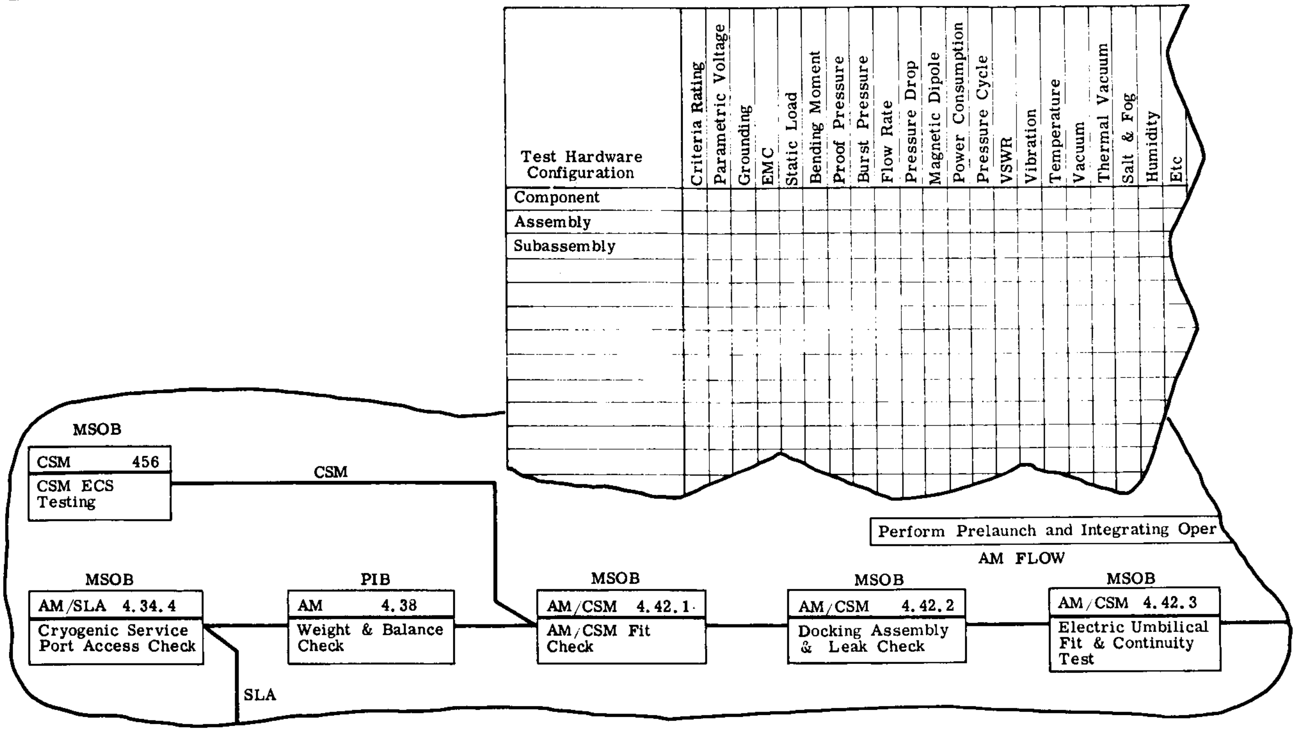


Figure VI-6 Test Flow and Matrix Samples

As work progressed, several coordination trips were made to MSFC to advise the principals there of our activities and to receive their comments on the test program. Information on existing MSFC test facilities and capabilities were also assembled on these trips to aid us in the forthcoming test planning activities.

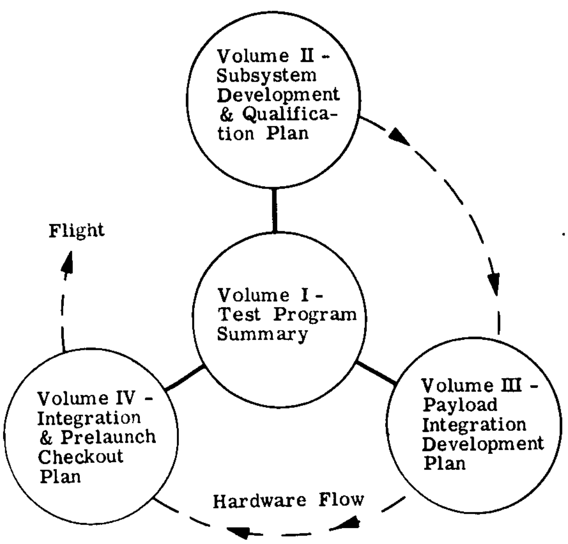


Figure VI-7 General Test Plan Interfaces and Hardware Flow

3. Test Planning - Early in January, primary emphasis was placed on the prepration of AAP Missions 1/2 and 3/4 test plans. These plans are contained in Volumes I thru IV of our General Test Plan, ED-2002-49, dated April 7, 1967. They are written in such a way that they may be used as a base for preparation of more detailed test plans. The plan outline and content were reviewed with MSFC laboratory personnel before writing commenced. Figure VI-7 shows the interrelationship of these four volumes, which are discussed in the following paragraphs.

a. <u>Test Program Summary, Volume I</u> - This volume establishes the test objectives, philosophies, and policies that govern the preparation and implementation of the other test plans, procedures, and operations. Included are descriptions and purposes of the various test categories and types of tests that we propose for AAP equipment, a description of the responsibilities and functions of other involved agencies and organizations relative to the testing function, an abstract of test program documentation, a description of the test support requirements necessary to accomplish the test program, and the program test flow and time-lines. This plan establishes the control methods that will be used to manage the test program.

b. <u>Subsystem Development and Qualification Plan, Volume II</u> - This plan is designed to be used through the development and qualification phase of mission components and subsystems. The plan specifies the individual tests required to ensure proper performance of the subsystems involved. Nonfunctional and functional test articles will be used to confirm component and subsystem preliminary designs before finalization of flight hardware design. The plan describes the testing necessary to achieve design confidence by evaluating hardware performance under ambient and selected environmental conditions.

c. <u>Payload Integration Development Plan, Volume III</u> - This plan describes the tests necessary to develop and qualify the integrated experiment carriers and combinations of integrated carriers. This phase of the test program is established in three sections.

1) <u>Development</u> - The development test program that we propose uses both nonfunctional and functional test articles to confirm conceptual designs before completion of flight hardware design. Nonfunctional mockups will be used to verify space allocations, equipment locations, cable and tube routing, equipment accessibility, man/machine compatibility, and verification of interfaces between carriers. Functional hardware in the form of breadboards, brassboards, and prototypes will be subjected to ambient and environmental tests to confirm proper design approach.

2) <u>Qualification</u> - Our qualification test program will normally be conducted on flight-configured prototype articles that have been subjected to production fabrication processes and that have passed the acceptance tests specified for the flight article. Certain ambient qualification tests that do not cause hardware degradation will be performed on the flight hardware.

We specify certain qualification tests of integrated experiment carriers to verify subsystem and system operation, experiment performance, and operation sequence. Performance will be evaluated at ambient and in the various environments that the flight hardware would be subjected to in the flight sequence. When practical, scale models will be used to obtain test data that may be used to establish qualification status of certain hardware.

3) Systems Design Verification - We specify that these tests be conducted on the combined integrated carriers in the launch and on-orbit configurations. The performance of these tests will demonstrate that all elements of a subsystem and system properly accomplish their intended functions without adverse effects on each other. We specify that tests be performed using flight hardware, flight-configured prototype hardware, and simulators or semi-functional mockups to verify the mechanical, fluid, electronic, and man/machine compatibilities between the integrated experiment carriers. This series of tests is further discussed in Subsection 4.

d. Integration and Prelaunch Checkout Plan, Volume IV - This plan describes the tasks and responsibilities for planning, scheduling, implementing, and controlling the integration and prelaunch checkout functions for the integrated experiment carriers at the payload integration facility and at KSC. The series of tests we specify in this plan verifies flight carrier interfaces, AAP modifications of these carrier systems, AAP subsystem add-ons, and experiment compatibility.

The AAP modifications are checked out by a series of individual system and experiment tests. The experiments are checked out by the application of stimuli using experiment-peculiar GSE and stimulus sources. After establishment of individual system and experiment compatibility, a series of combined system tests will be performed culminating in a simulated mission sequence.

This plan specifies and schedules the AAP hardware checkout requirements at KSC from receiving inspection through launch. Throughout this series of tests, all interfacing carrier loads, responses, and characteristics will be provided either by the use of flight hardware simulators or prototypes.

e. Future Mission Planning - One of the functions of test planning is the identification and subsequent study of potential problem areas. We have recognized some test problem areas within future mission test programs as they are now defined. As the future AAP mission requirements become more definite, additional problem areas will be identified. Some of the recognized problem areas evaluated and requiring future study are discussed in the following paragraphs.

Mission 5/6/7/8 is a one-year-long mission requiring increased systems reliability. An evaluation of these systems shows that test methods to demonstrate satisfactory life performance characteristics and reliability need to be refined. The tests necessary to establish the size and number of rechargeable batteries compared with power requirements, and such factors as battery overcharge protection, charge rate, cycle life, and discharge depth have also been considered.

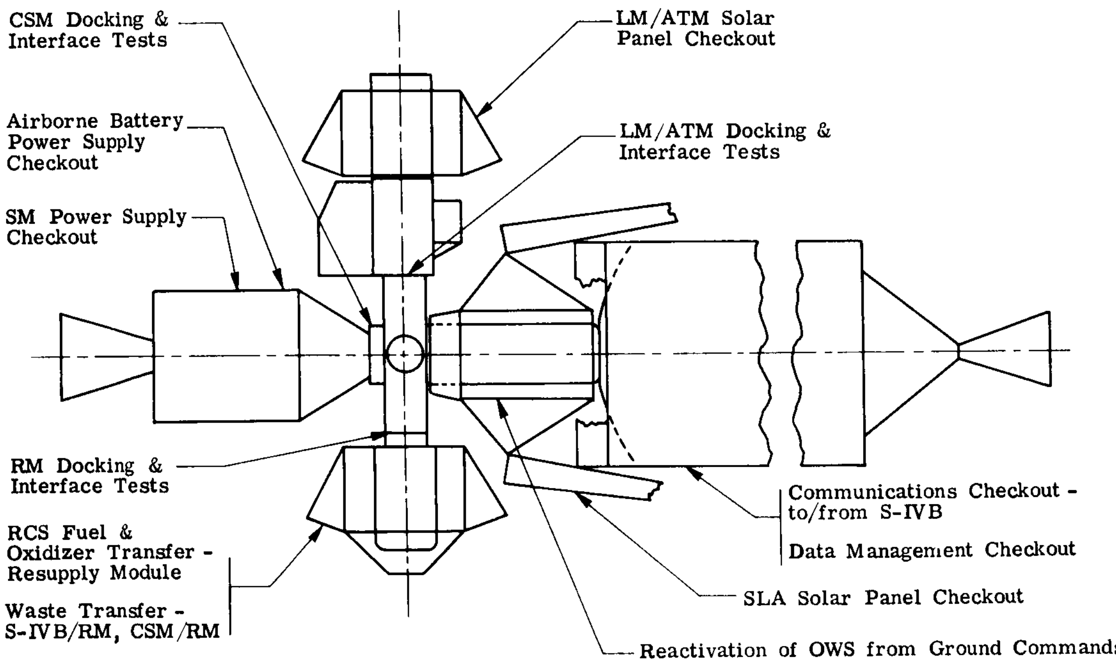
Flight 9, consisting of a CSM and an APP-B rack carrier, requires pointing to the local vertical to an accuracy beyond the capability of existing systems. To satisfy pointing requirements, a local vertical sensing system (LVS) and a control moment gyro (CMG) control system will be used. Test methods and the test equipment necessary to verify the accuracy of the pointing system have also been considered.

Flights 17 and 18 place AAP payloads in a synchronous orbit, subjecting these payloads to deep-space environments. The planned orbit is within the outer fringe of the Van Allen belt of trapped radiation and is scheduled during a period of high solar flare activity. Preliminary investigations of the tests required to evaluate payload performance in these environments indicate a need for in-depth studies in these areas.

Missions 25 thru 34 are extended-duration, low earth-orbit missions requiring a long-duration power system, such as a radioisotope-powered closed Brayton cycle system. Consideration has been given to the development test program necessary to determine the effects of space environments on such a system, and the radiation protection and thermal control requirements.

The cluster tests that evolved from the Missions 1/2, 3/4 test planning effort are applicable to other AAP missions. Different cluster configurations present different shadowing effects, affecting thermal balance and solar array power output. Test techniques have been evaluated to determine the best test methods for determining the effects of shadowing. Mockup and prototype models from one cluster test program may be refurbished and used for subsequent cluster test programs.

4. Intercarrier Verification Test Program - One of the most significant factors that has appeared in development of the AAP test program is the requirement for an intercarrier verification or cluster test program. The magnitude and complexity of the interfaces between the various Flight 1 thru 4 elements that comprise the cluster configuration dictate this requirement. This cluster and representative integrated carrier tests are shown in Figure VI-8.



Note: 1. LM SS/Rack omitted for clarity.

2. Integrated Carrier Tests:

1) Mission simulation;
2) EMC tests;
3) Display and control between all modules;
4) Power supply interface and interaction;
5) O_2/N_2 gas pressure variation;
6) Ground/orbit operation compatibility;
7) Contingency verification;
8) Deactivation and securing.

Figure VI-8 Missions 1/2, 3/4 On-Orbit Configuration

Normally, design verification testing is performed on flight-configured prototype test specimens. For the AAP cluster verification, the feasibility of this approach is questionable because of cost, schedule compatibility, and prototype availability considerations. We conducted a study in this area and published the results in Cluster Verification Test Justification and Feasibility Report, ED-2002-68, dated March 17, 1967.

Various test configuration candidates were evaluated to determine the best test configuration using a mixture of prototypes, simulators, and semifunctional mockups. This evaluation has been published in Configuration Trade Study Cluster Verification Test Report, ED-2002-69, dated March 17, 1967.

Through systems analysis and meetings with various MSFC personnel, the selection of candidates was simplified. The candidates selected for evaluation are shown in Table VI-1. Figure VI-9 graphically portrays the results of this evaluation. It is shown that good test results can be achieved with the elements of Candidates 1, 2, or 3. In all three candidates, an LM&SS semifunctional mockup (SFM) was used; the variable was the S-IVB. In Figure VI-9, supplemental tests refer to partial cluster or interelement tests at a level lower than full cluster tests at MSFC.

Table VI-1 Candidate Configurations

CANDIDATE	S-IVB	IU	SLA	AM	MDA	RM	LM	ATM/RACK	CSM	LM&SS
1	P	P	P	P	P	P	P	P	P	(S) + SFM
2	S	P	P	P	P	P	P	P	P	(S) + SFM
3	SFM	P	P	P	P	P	P	P	P	(S) + SFM
4	P	P	P	P	P	P	S	P	S	S
5	S	P	P	P	P	P	S	P	S	S
6	SFM	P	P	P	P	P	P	P	S	SFM
7	SFM	P	P	P	P	P	S	P	P	SFM

S = simulator; P = prototype; SFM = semifunctional mockup.

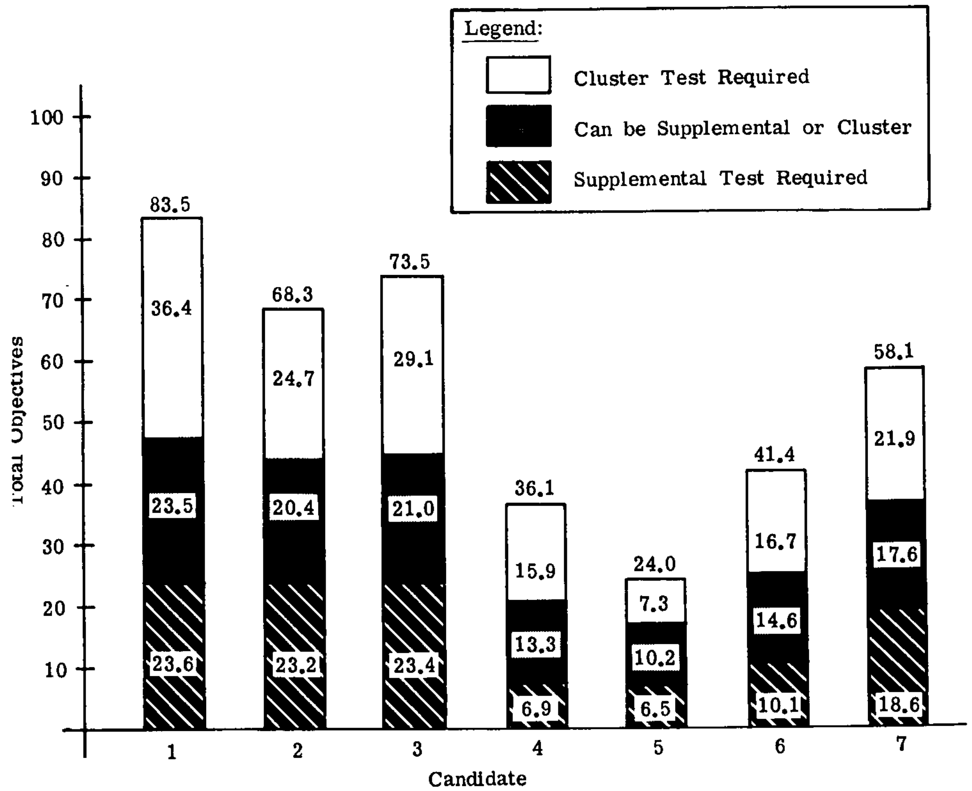


Figure VI-9 Candidate Configuration vs Percent of Total Objectives

One major problem area in this test phase is the accomplishment of electromagnetic compatibility (EMC) tests. The objective of these tests, which must be conducted in an area free of extraneous RF radiation, is to verify the EMC of the integrated experiment modules, support subsystems, and experiments when operated in a mission sequence. Preliminary analysis indicates that the EMC tests can be performed in MSFC building 4708 or 4755 depending on final cluster configuration.

To verify that the S-IVB hydrogen tank can be properly purged of residual hydrogen, we recommend that an in-flight venting test be performed on a tank used on an Apollo flight preceding the launch of AAP-2.

While the foregoing discussion of cluster testing was accomplished on prototype hardware to verify system design, cluster testing is also required on development test hardware and on the flight articles. Development cluster testing is performed to confirm man/machine compatibility, tube and cable routing, accessibility, etc. Testing of the integrated flight articles ensures that these articles will perform as specified before the launch of each flight. These tests should be performed at KSC to insure that all carriers can dock and interface as required. Where flight hardware is not available, master gages and simulators should be used.

5. Flight AAP-2 Testing - The test program that has eventually evolved from our Phase C planning activities has been detailed in the test plans identified in the preceding section. A summary of the major tests that we feel are essential to the success of Flight 2 is presented here and shown in Figure VI-10.

In general, the pacing test tasks associated with Flight AAP-2 are those of developing the OWS and its compatibility with the cluster configuration. Cluster configuration testing was discussed in Subsection 4 above.

a. OWS Testing - The test program we propose for the OWS commences with tests to demonstrate the feasibility of the design modifications that permit the S-IVB hydrogen tank to be used as a habitable working area in space. Maintaining a proper thermal balance has made necessary the following tests:

Scale model and major assembly tests - These tests are needed to obtain data to support system design and to provide instrumentation points for future tests. Major assembly tests will require thermal vacuum test facilities;

Prototype thermal vacuum tests - These tests, to be performed on the S-IVB or combinations of the S-IVB, AM, and MDA, will provide design development data and will satisfy qualification test requirements.

OWS mockup activities will also be required to check the experiment installation locations and man/machine compatibility. During the static firing test of the flight article, we recommend that all modifications that will normally be installed at the time of launch be installed. The OWS checkout at KSC should include a verification of tank passivation.

b. MDA Testing - Since the MDA is a new development item, the normal series of development and qualification tests will be required. Because it is to be the hub of the cluster, the structural tests must be emphasized. We recommend that static, dynamic, and docking load tests as well as an acoustic test be performed on an MDA prototype or structural test models as applicable.

Sufficient testing to demonstrate man/machine, experiment storage, and MDA-to-cluster interface compatibility must be accomplished on mockups and prototypes.

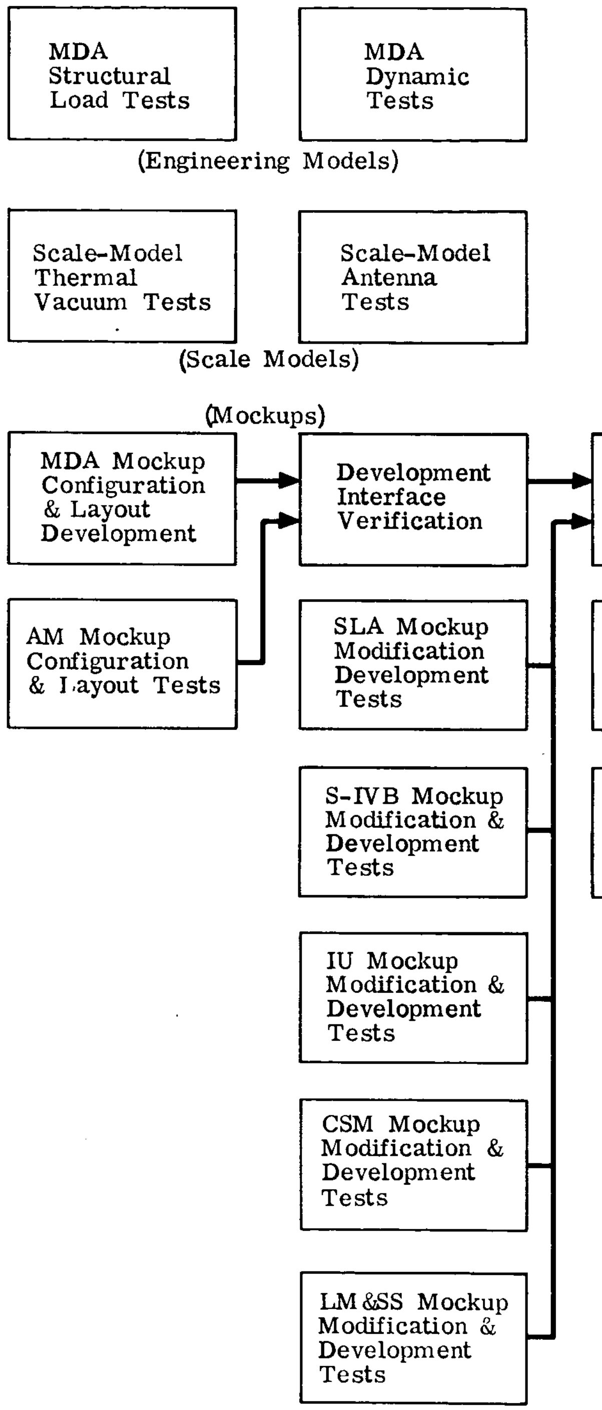
MDA acceptance tests should include a low-level vibration test, experiment installation fit check, and mass properties verification. At KSC, the MDA interfaces with other experiment modules should be verified with actual flight modules, if available. For example, the CSM and LM&SS rack from Flight AAP-1 should be diverted into the Flight 2 checkout flow and their interfaces verified. Prototypes or simulators of Flight 3 and 4 experiment modules should be used to check those interfaces of the MDA.

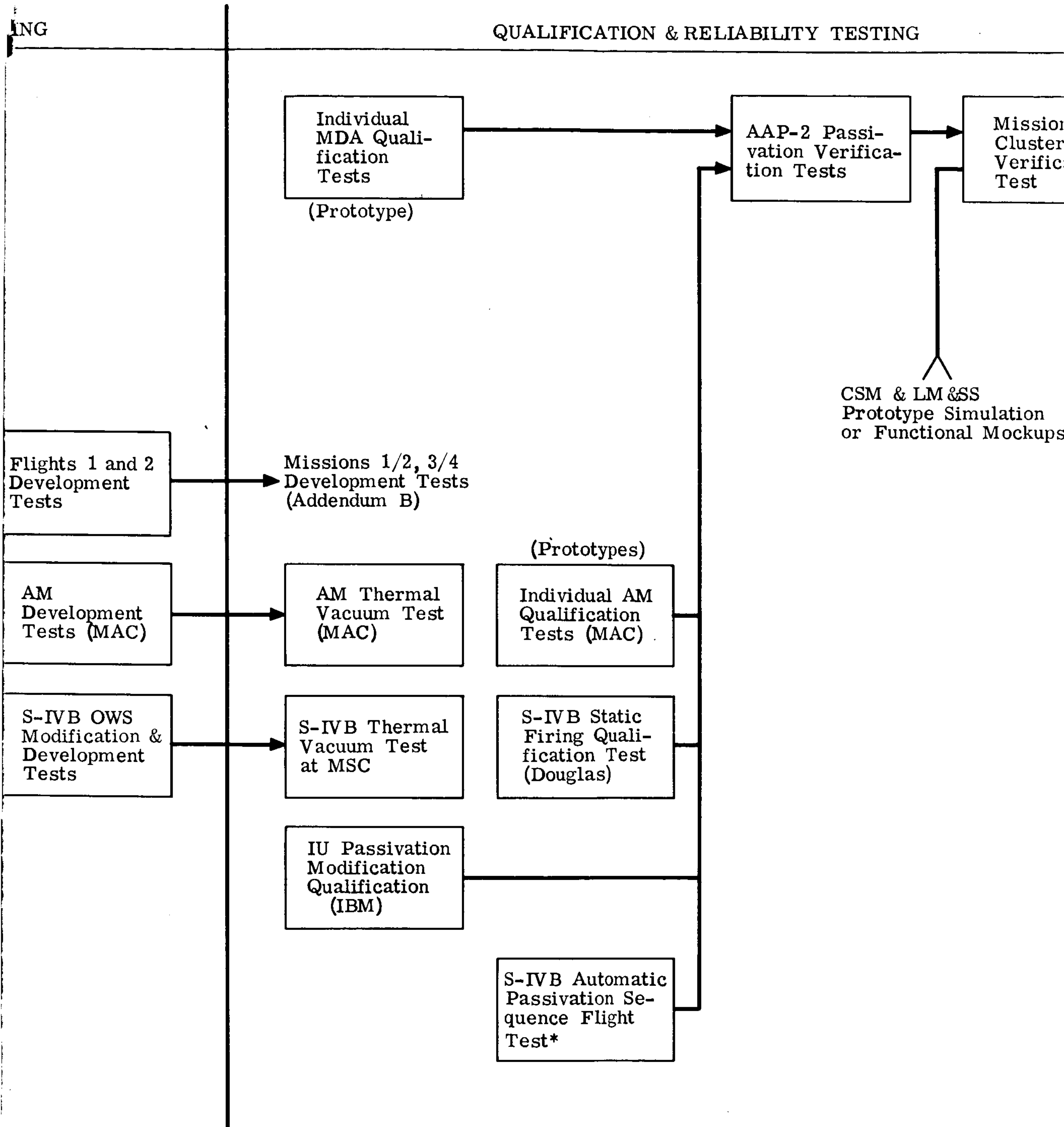
6. Flight AAP-4 Testing - The development of the ATM rack and its compatibility with the cluster are the primary test objectives of the Flight AAP-4 test program. The cluster test program has already been discussed. The ATM rack test program, summarized in Figure VI-11, will include numerous development and qualification tests since it is a new development item. Due to the critical pointing and temperature tolerances associated with the ATM experiments, we recommend that major test emphasis be placed in the thermal balance and pointing control development areas.

Mockup tests to verify optimum support subsystem and experiment location will be required, as will early thermal vacuum tests on thermal models of the individual rack and ATM package. The data that the scale-model tests provide should permit design and fabrication of prototype models that will also be subjected to thermal vacuum testing. This test should be preceded by a thorough analysis to determine vacuum chamber operation and the solar simulation requirements. This is necessary since the objectives of this test, in addition to thermal balance demonstration, include verification of integrated experiment performance and determination of experiment pointing misalignments due to thermal distortions. Because of the exact tolerances specified for ATM performance, the flight article should also be subjected to a thermal vacuum test.

The development and qualification of the pointing control system (PCS) will require close attention. Perhaps the most significant problem will be determination of ATM rack inaccuracies due to individual PCS element tolerance buildup. We recommend further detailed analysis of such problems to establish the proper test methods and test equipment design to perform the tests.

DESIGN DEVELOPMENT TEST





*This Test will be performed on an Apollo Flight with the IU & S-IVB passivation modification added.

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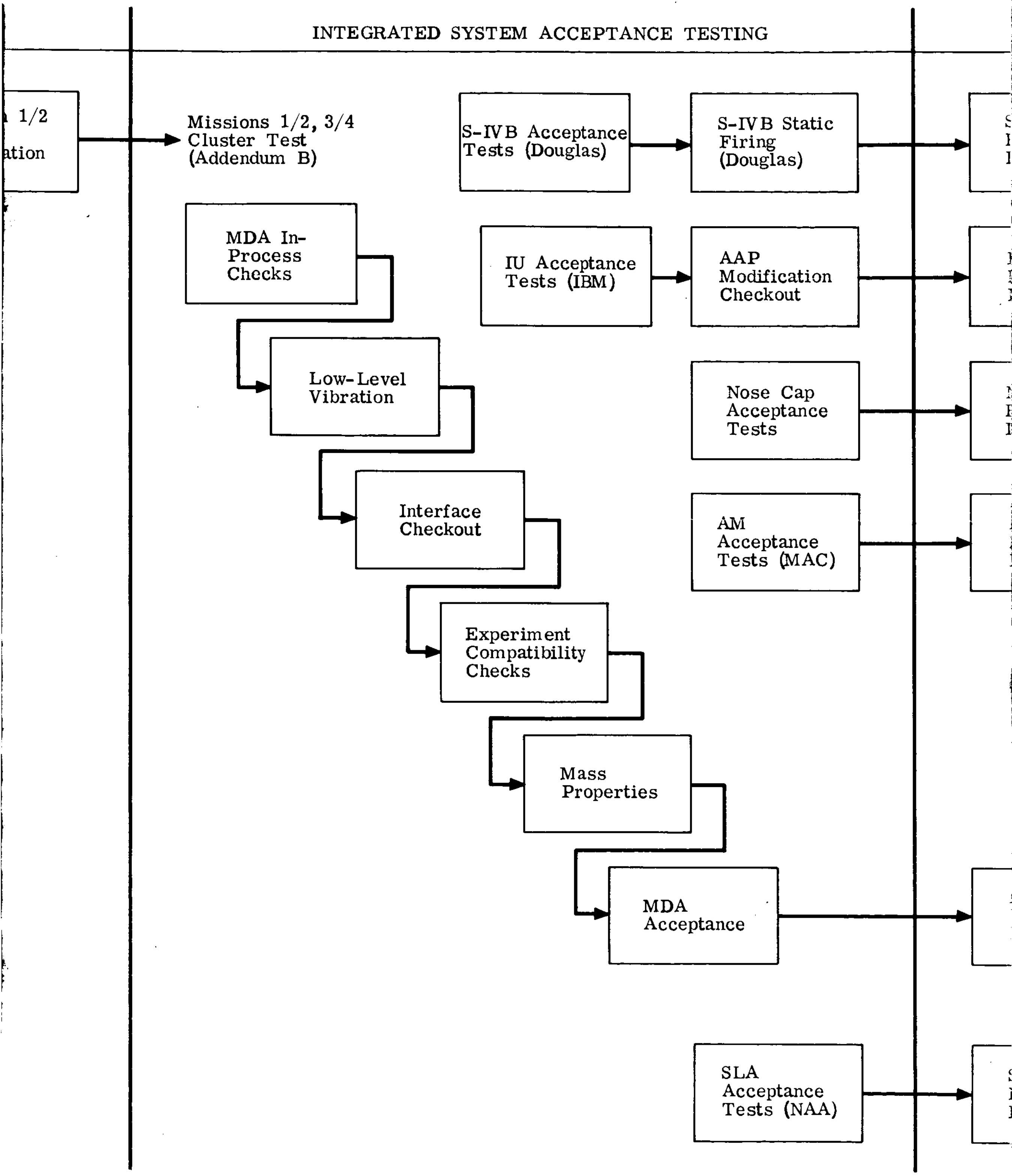
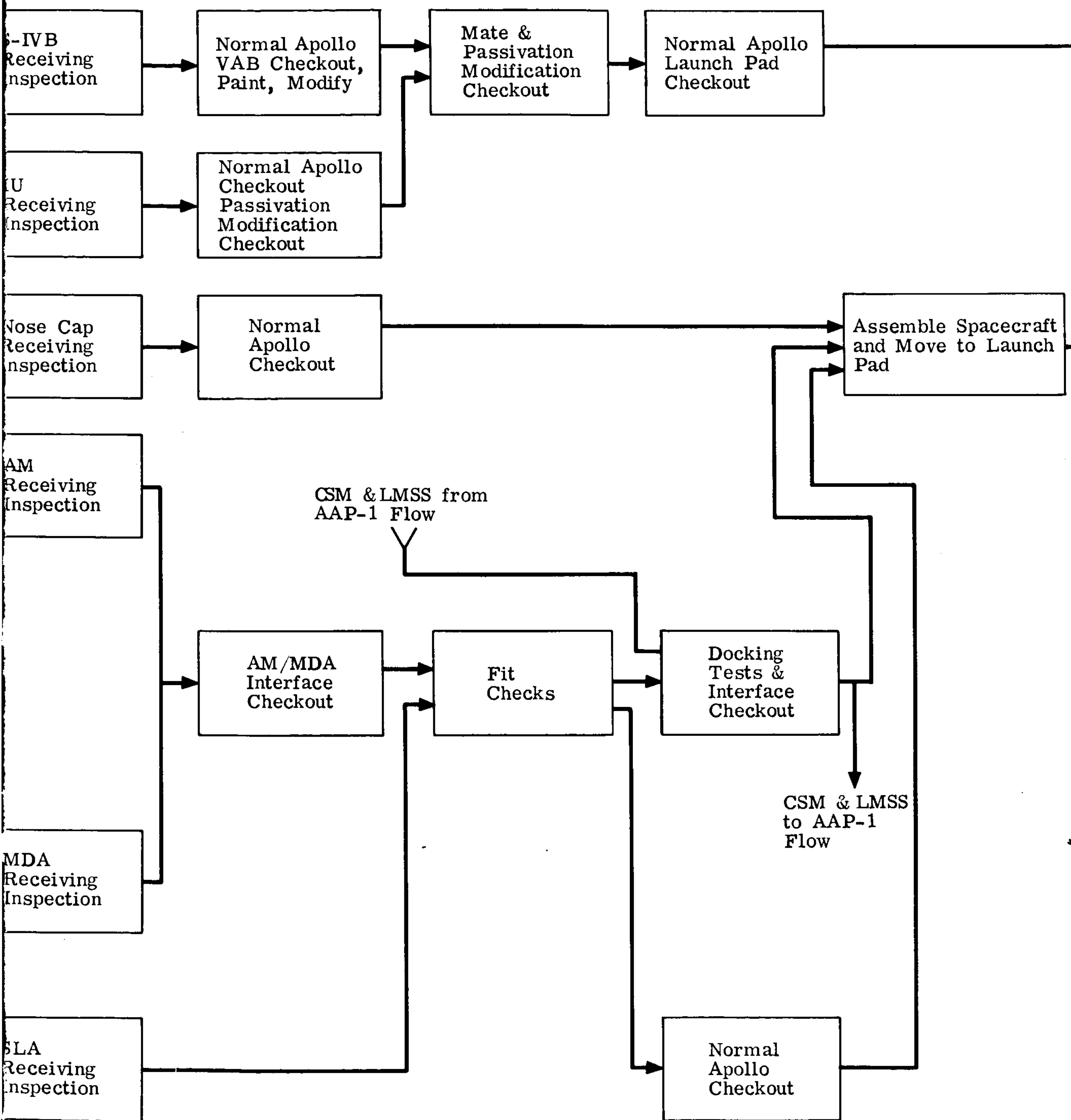


INTEGRATED SYSTEM ACCEPTANCE TESTING
1/2
ation
Missions 1/2, 3/4 Cluster Test (Addendum B)
S-IVB Acceptance Tests (Douglas)
S-IVB Static Firing (Douglas)
MDA In-Process Checks
IU Acceptance Tests (IBM)
AAP Modification Checkout
Low-Level Vibration
Nose Cap Acceptance Tests
Interface Checkout
AM Acceptance Tests (MAC)
Experiment Compatibility Checks
Mass Properties
MDA Acceptance
SLA Acceptance Tests (NAA)



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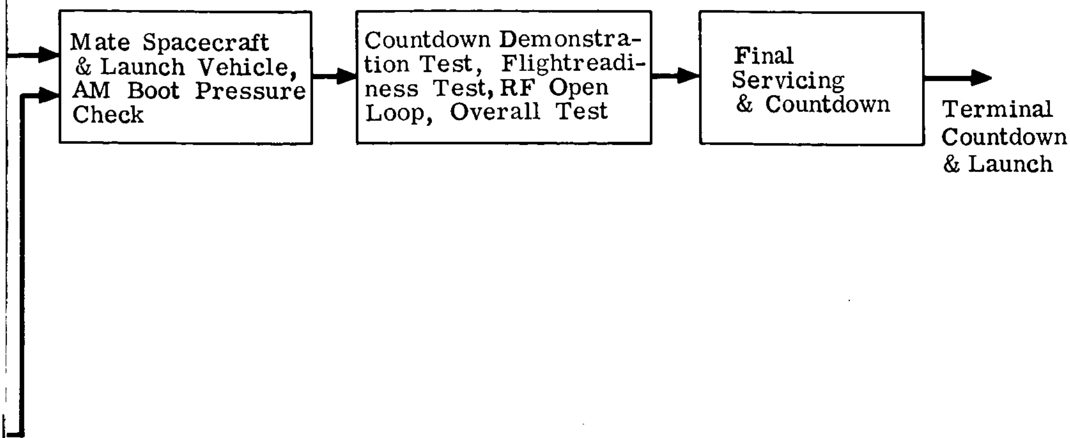
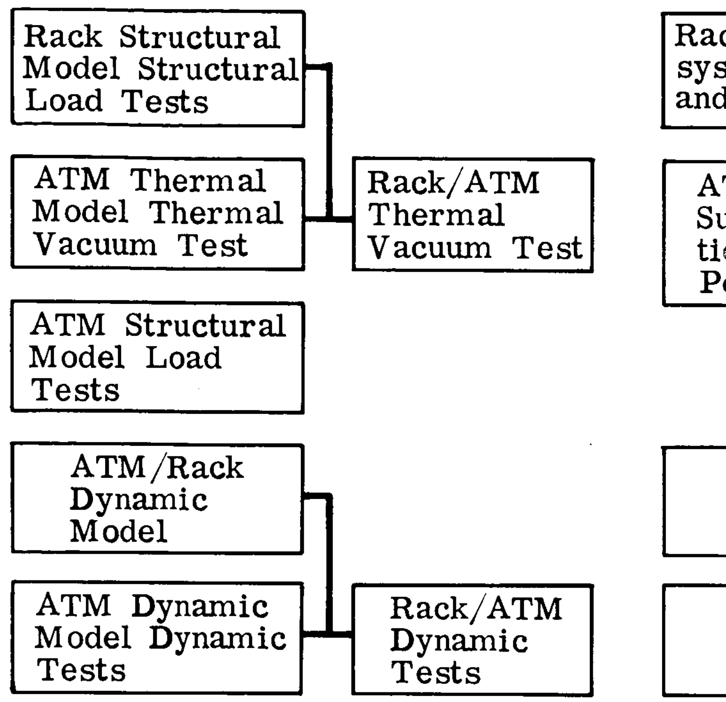
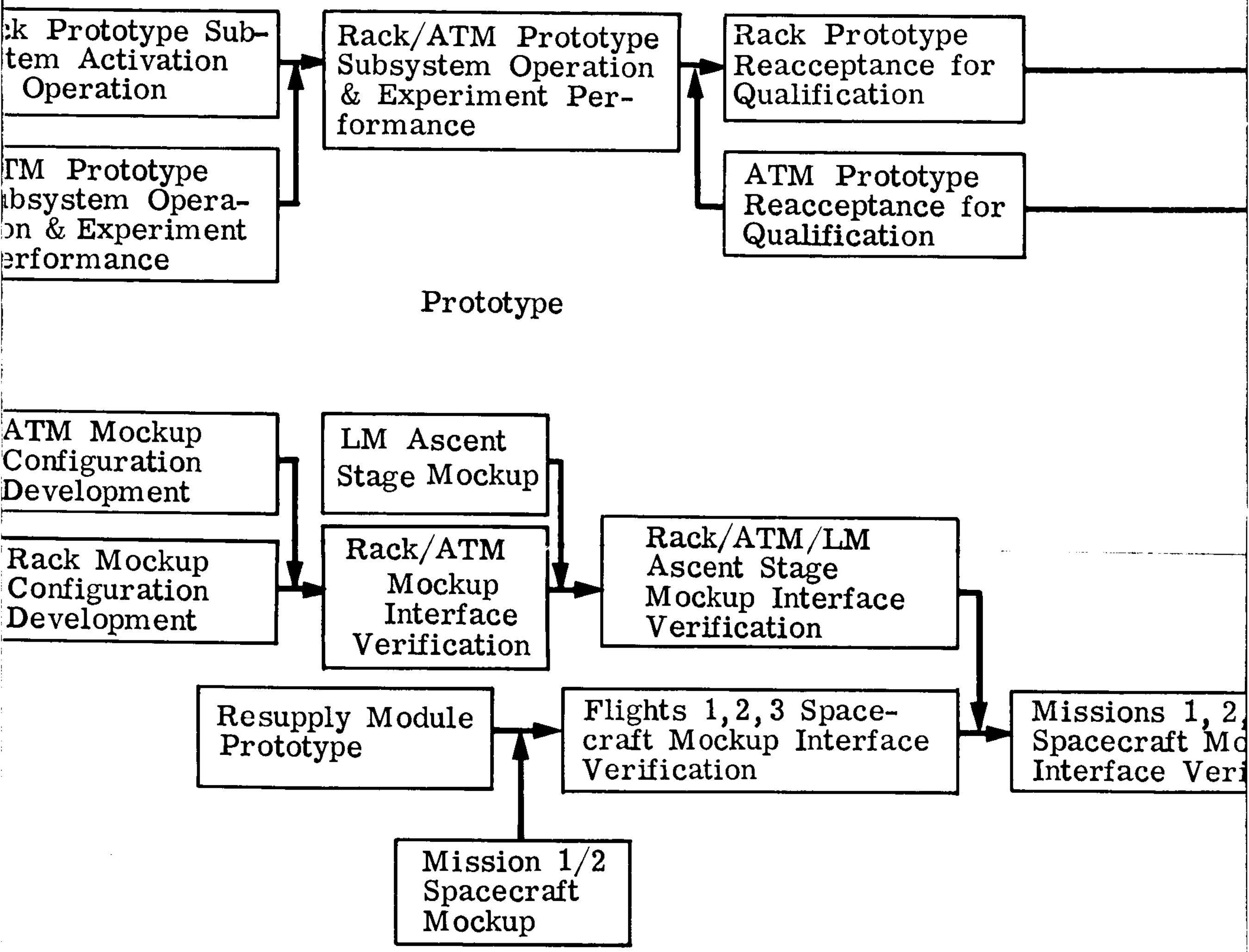


Figure VI-10 Flight AAP-2 Test and Checkout Sequence Flow



(Engineering Model)

DESIGN DEVELOPMENT TESTING



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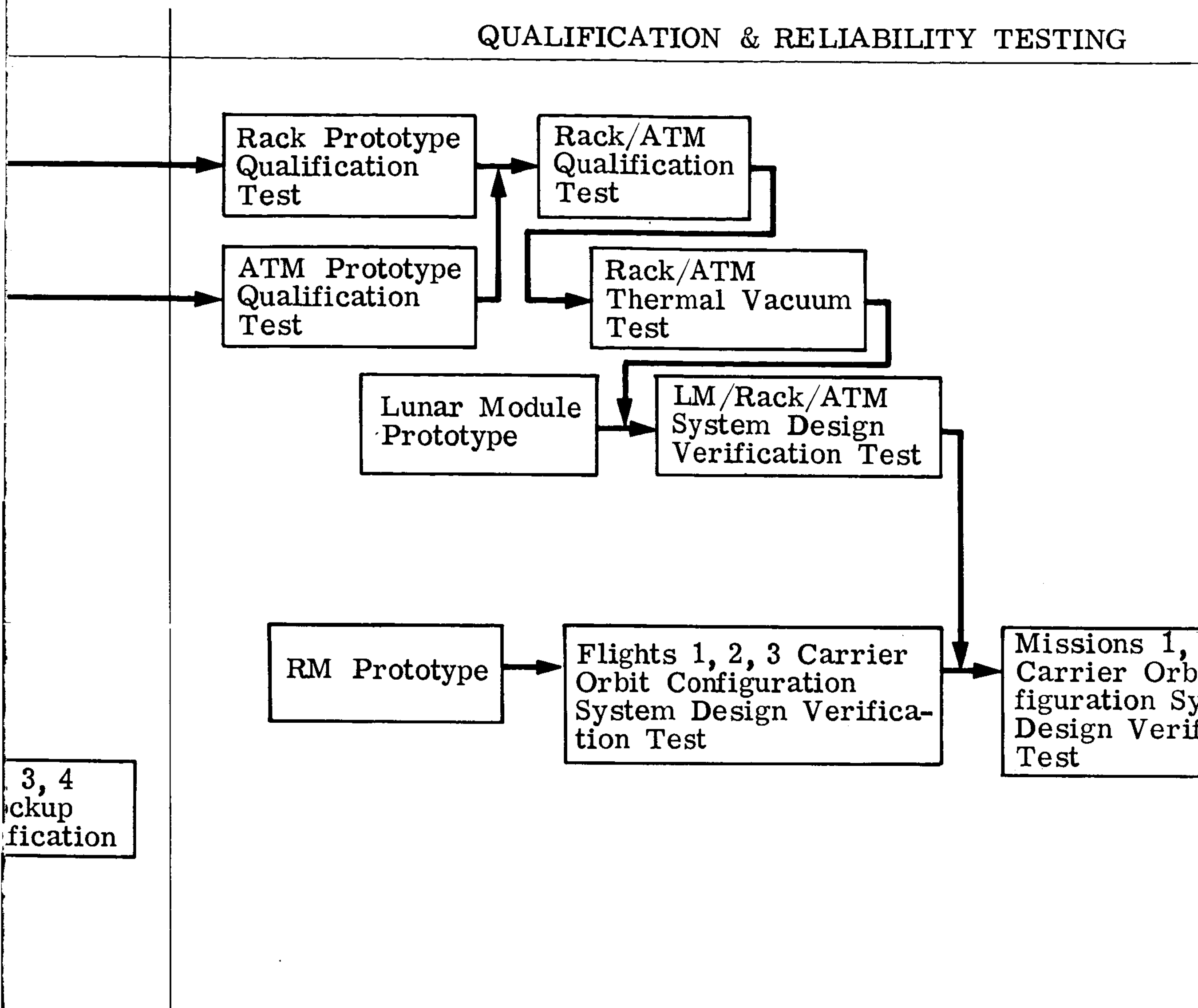

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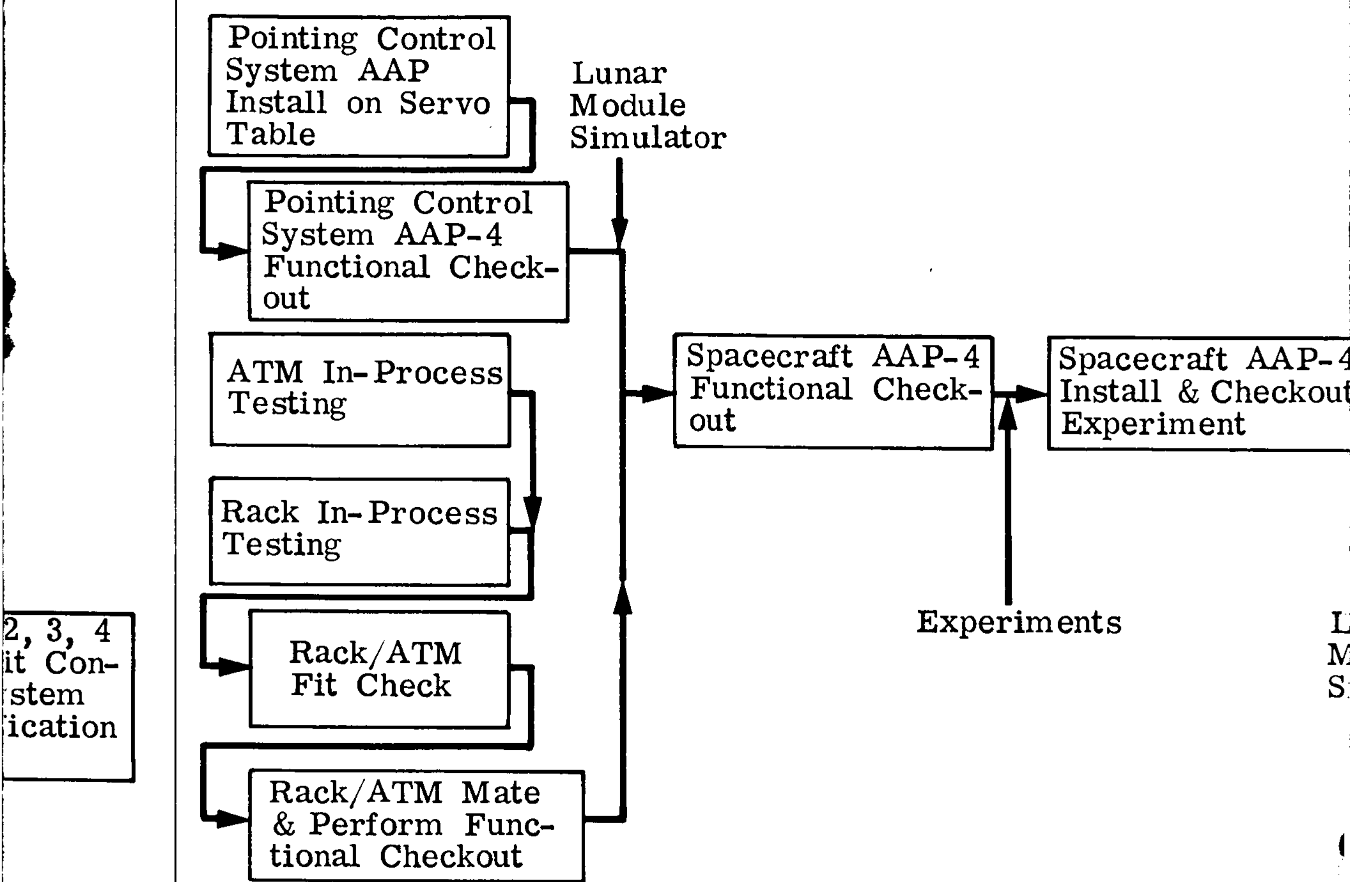
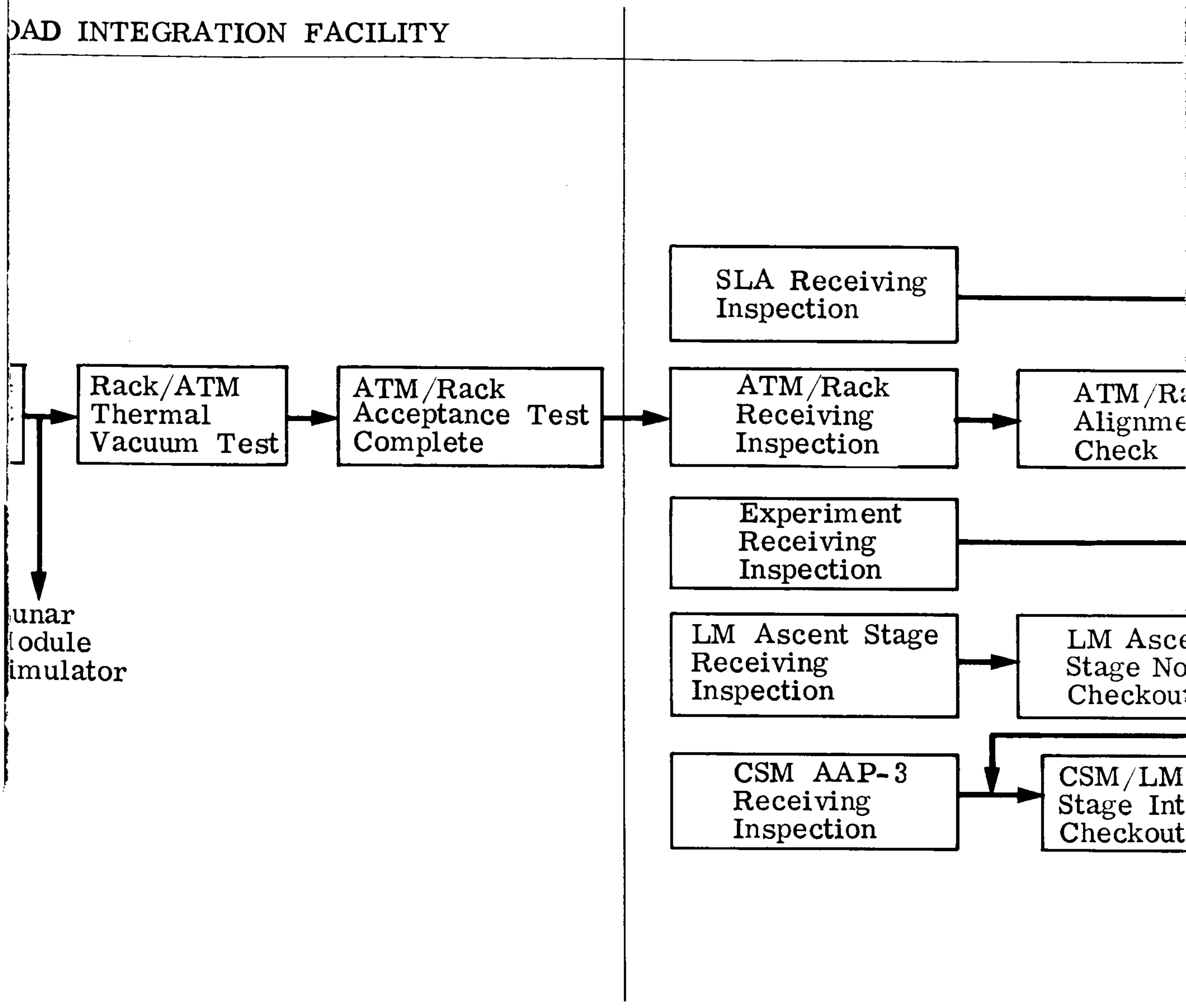
INTEGRATED SYSTEMS ACCEPTANCE TESTING, PAYLO





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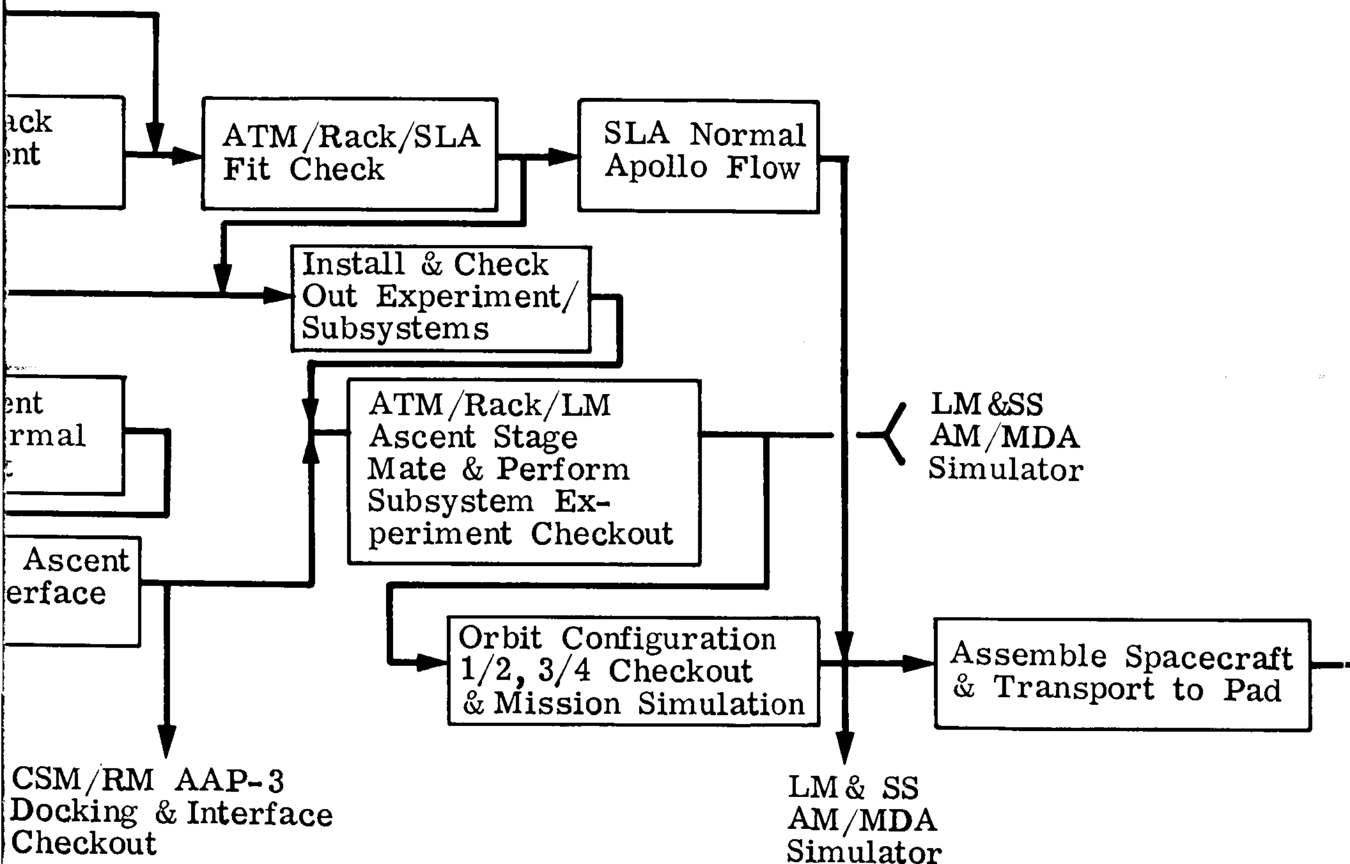
VI-23 D



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VI-23 E

OPERATIONS, KSC

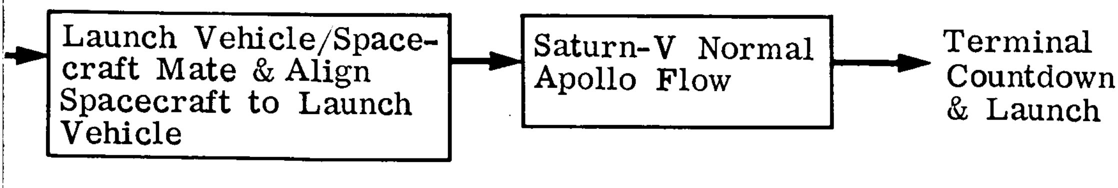

Figure VI-11 Flight AAP-4 Test and Checkout Sequence Flow

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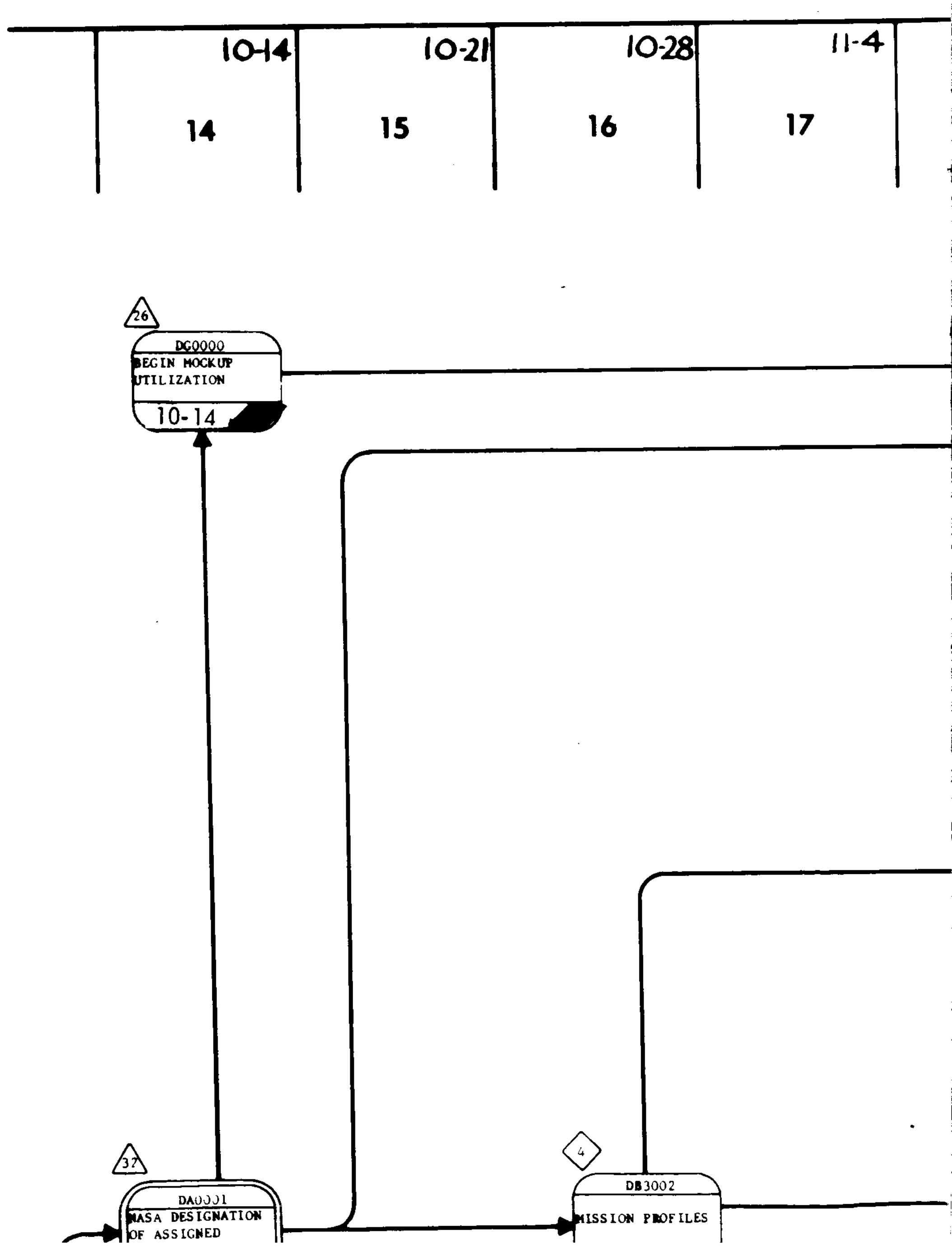

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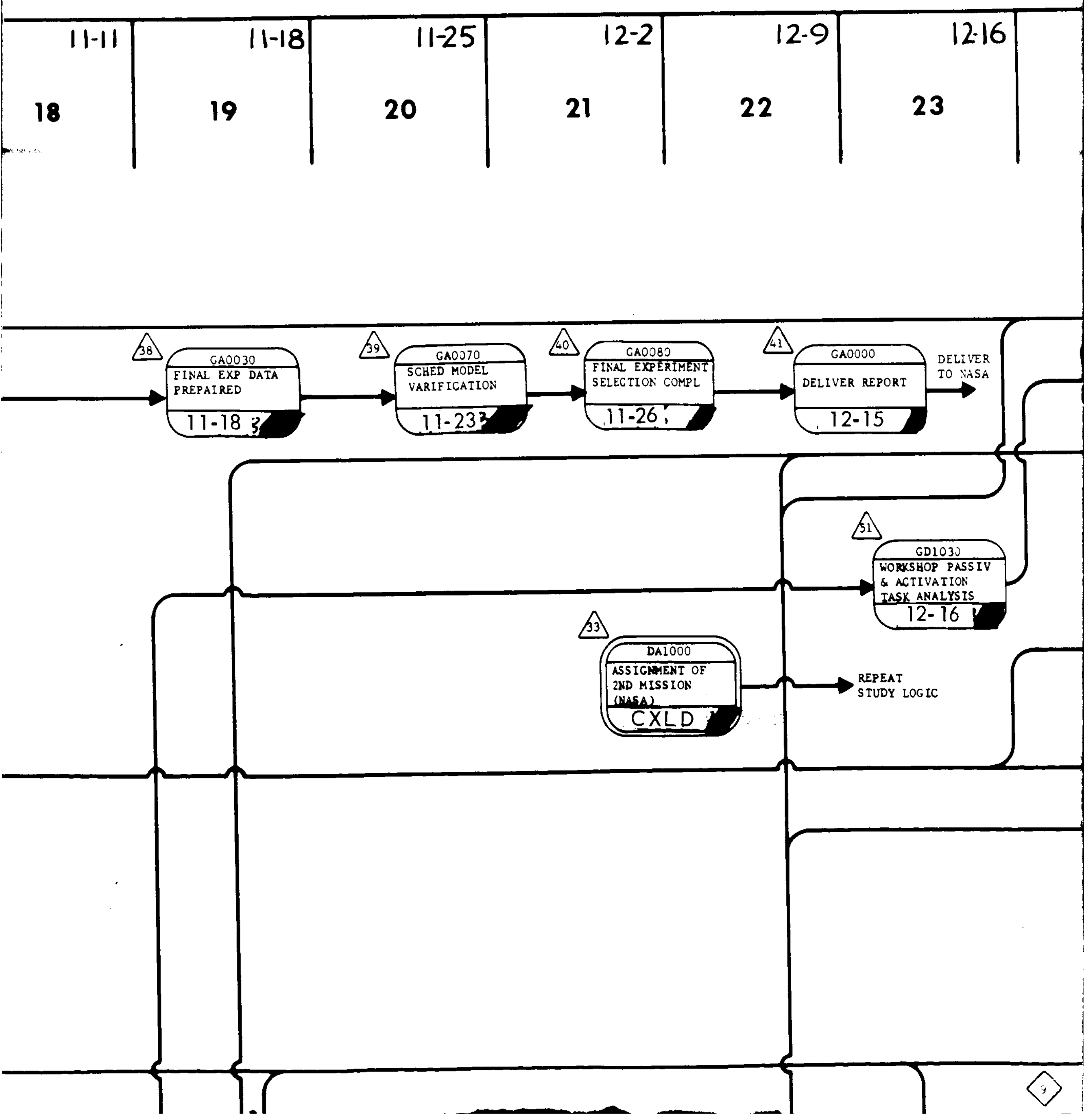

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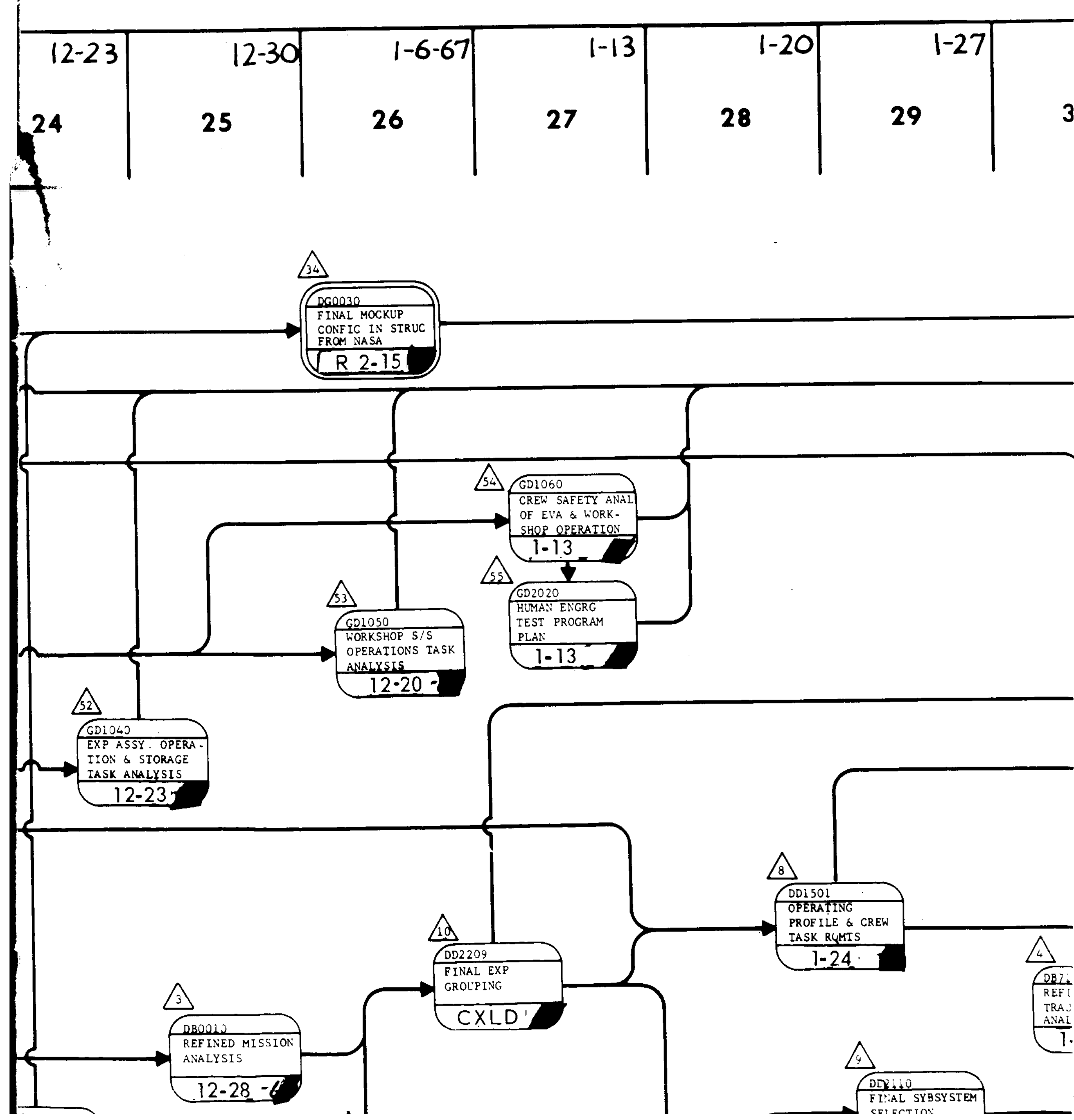

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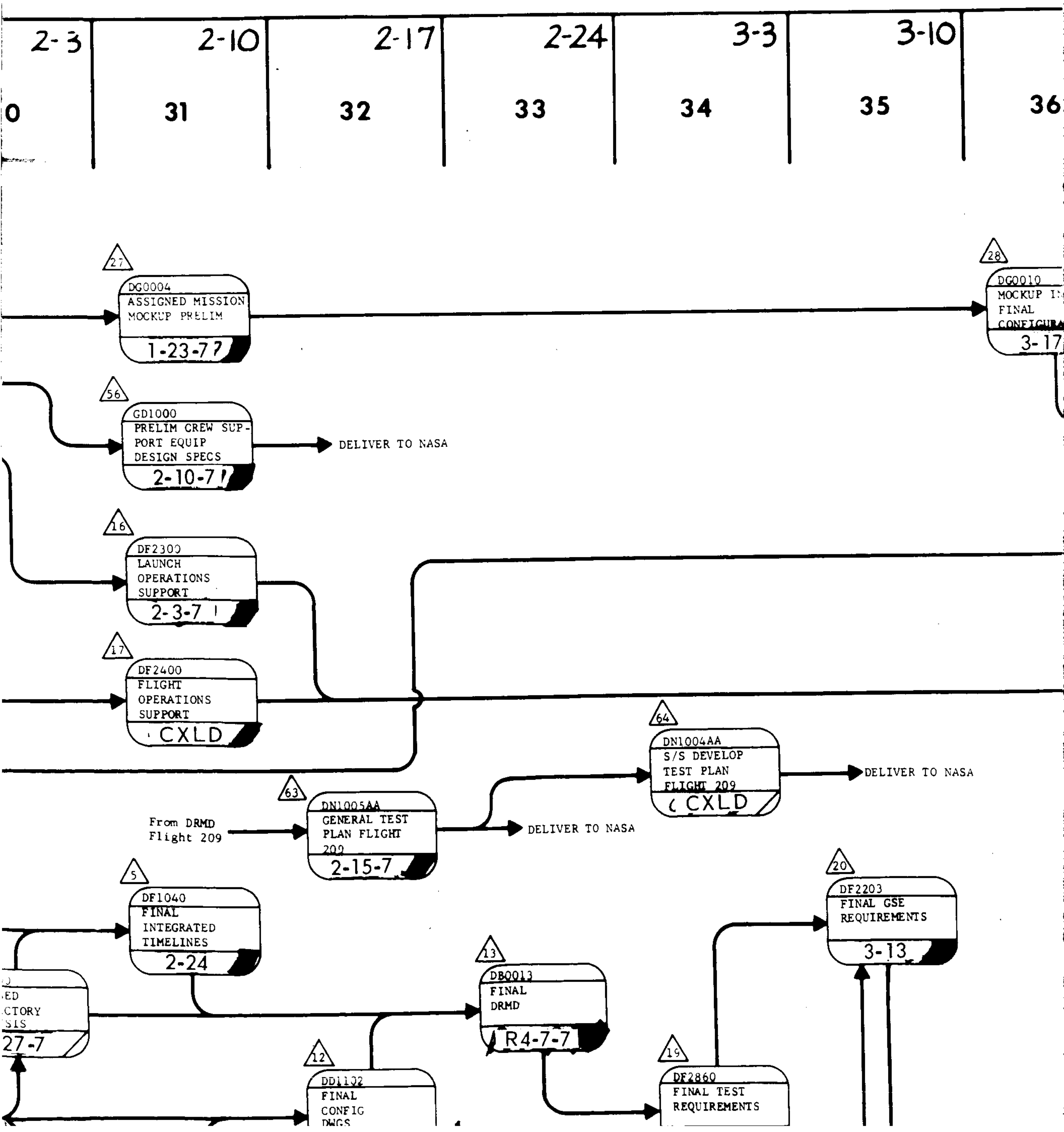

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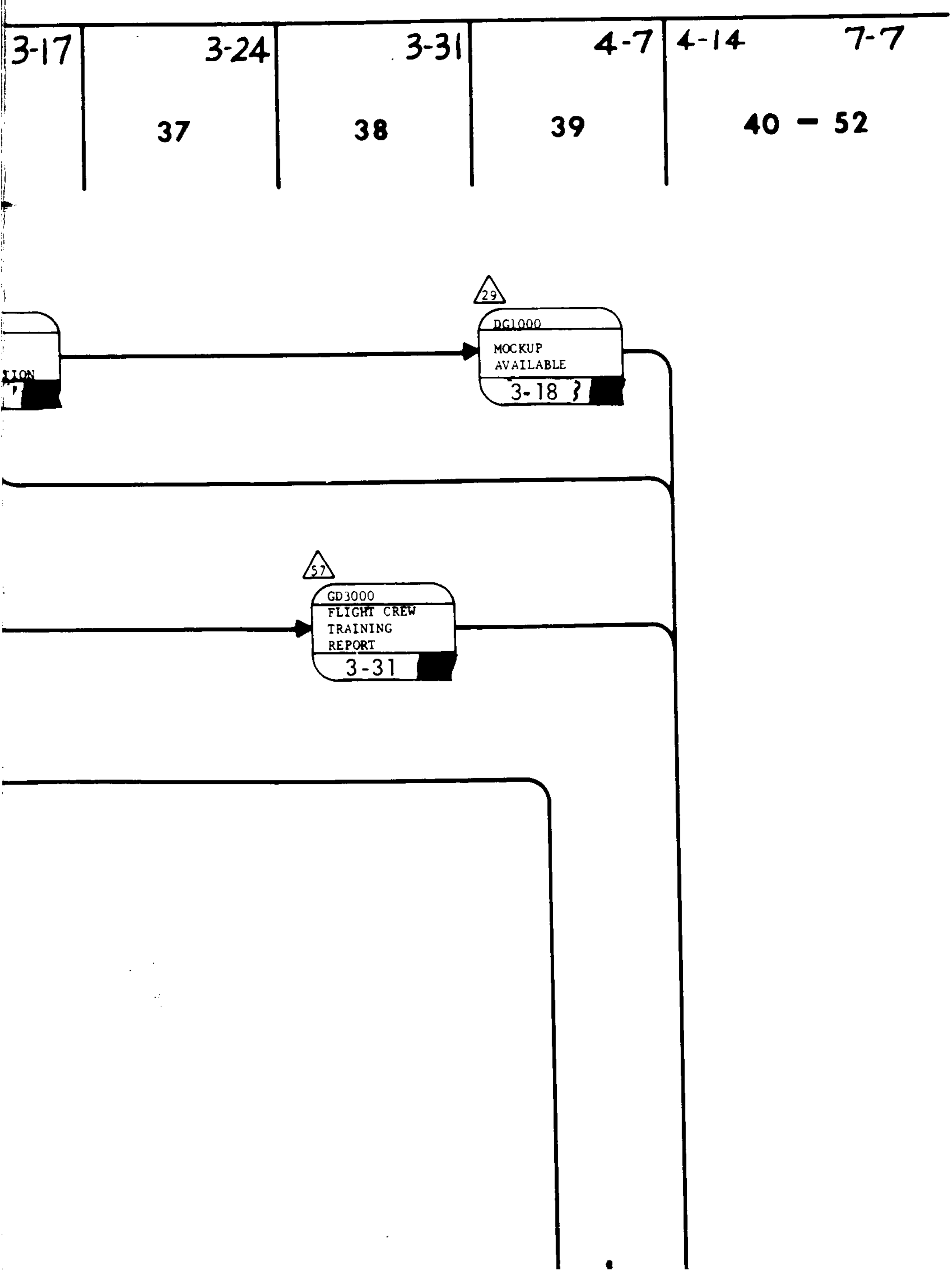

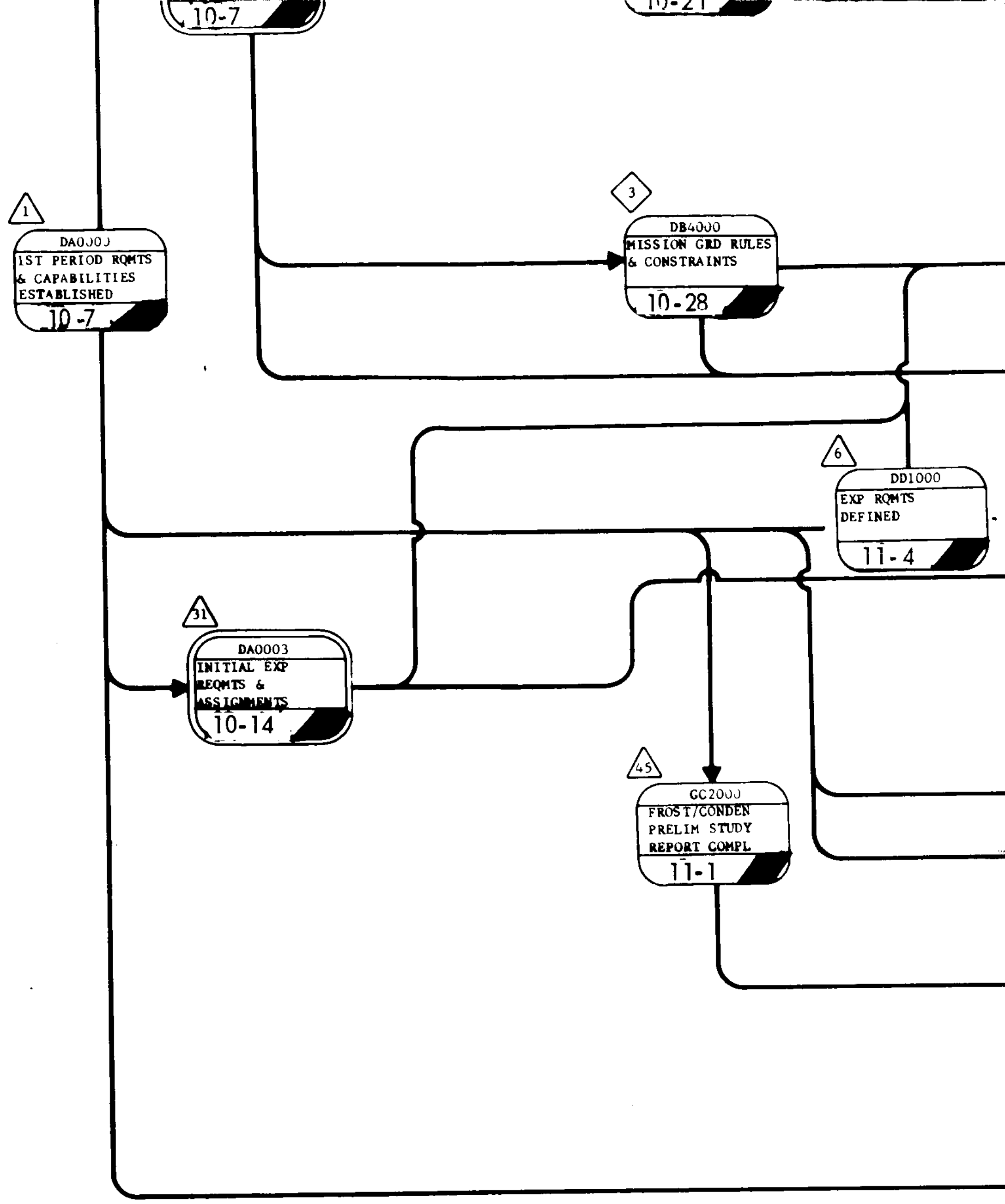

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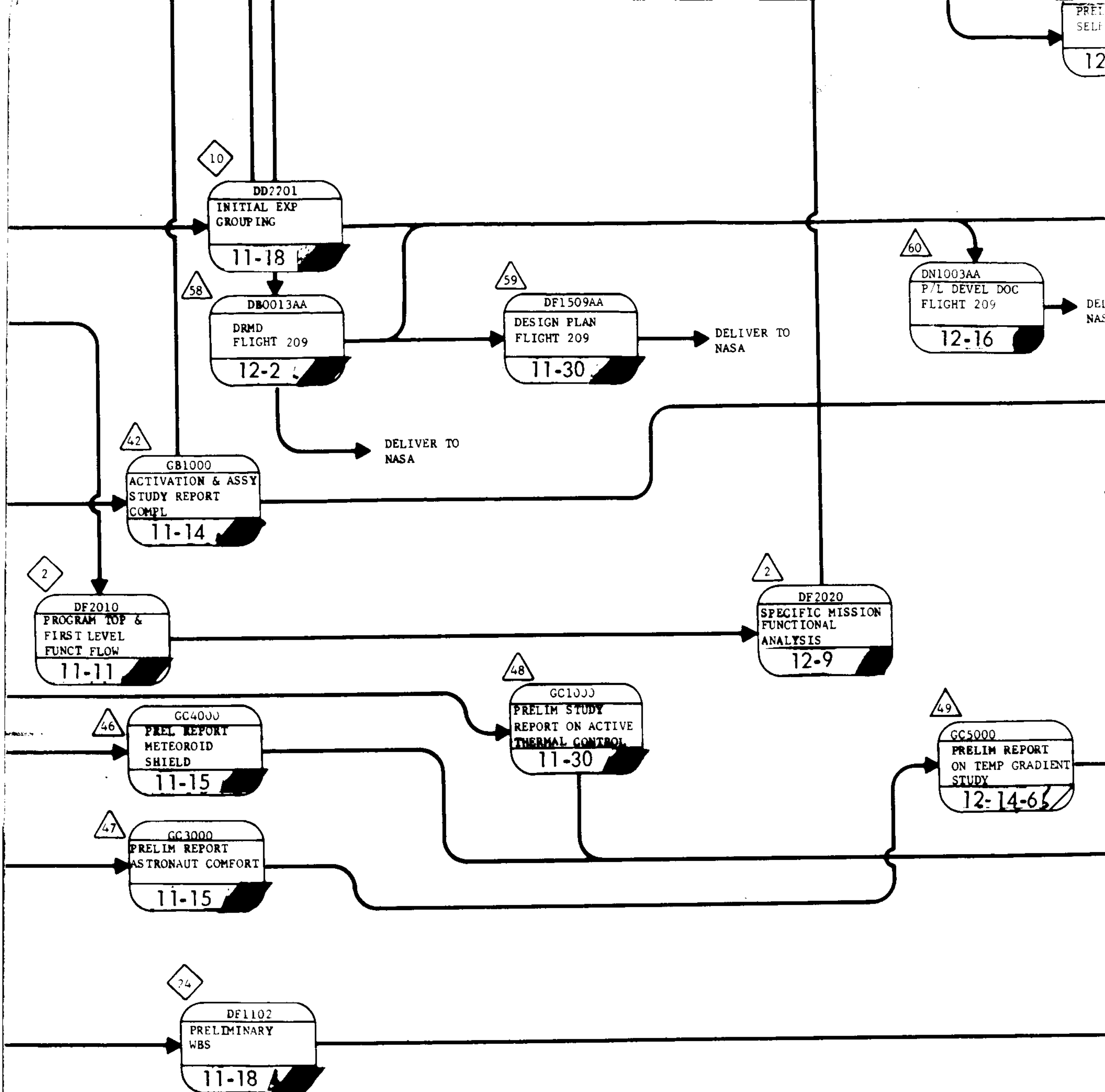

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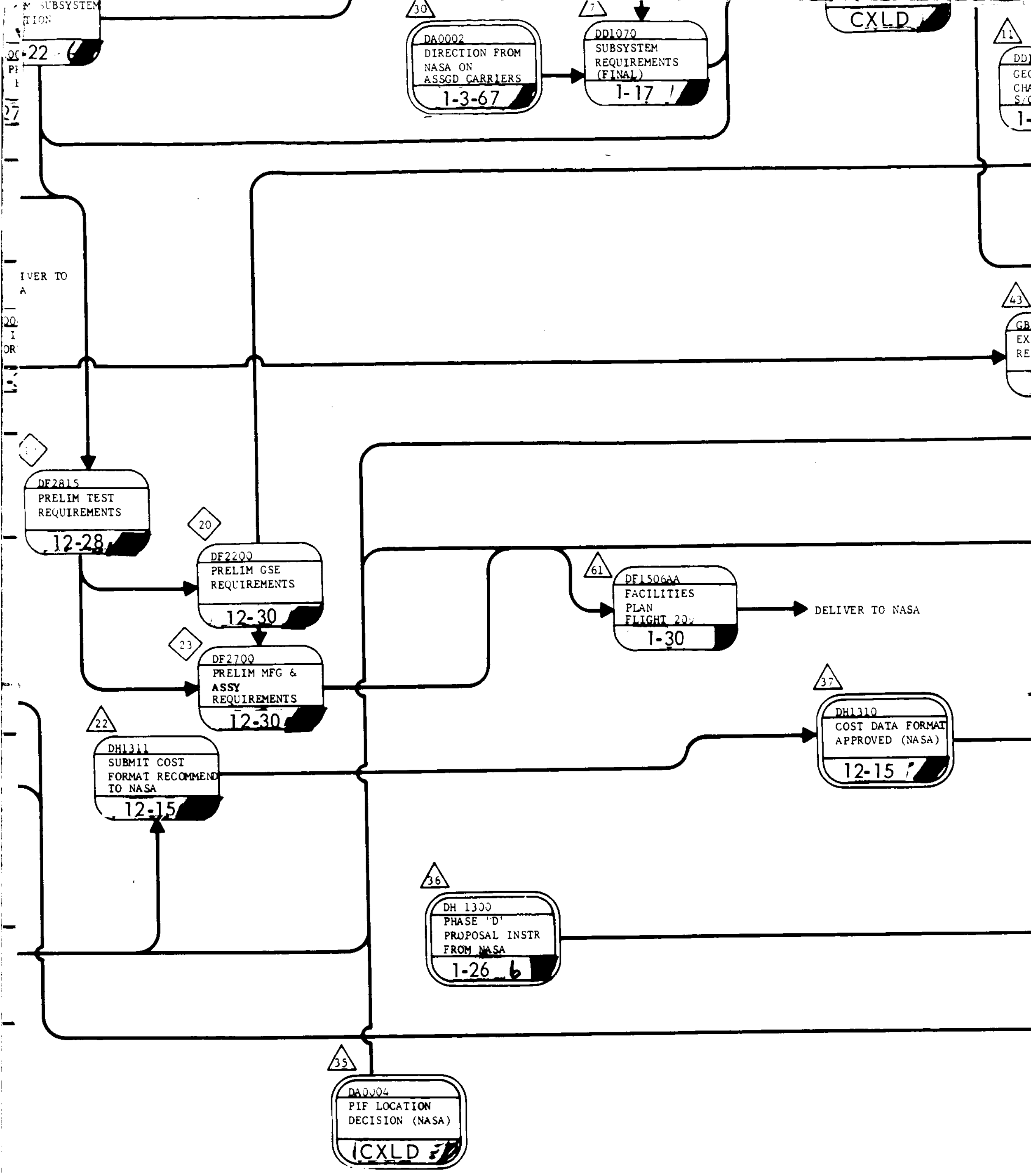

MARTIN MARIETTA CORPORATION

DENVER DIVISION

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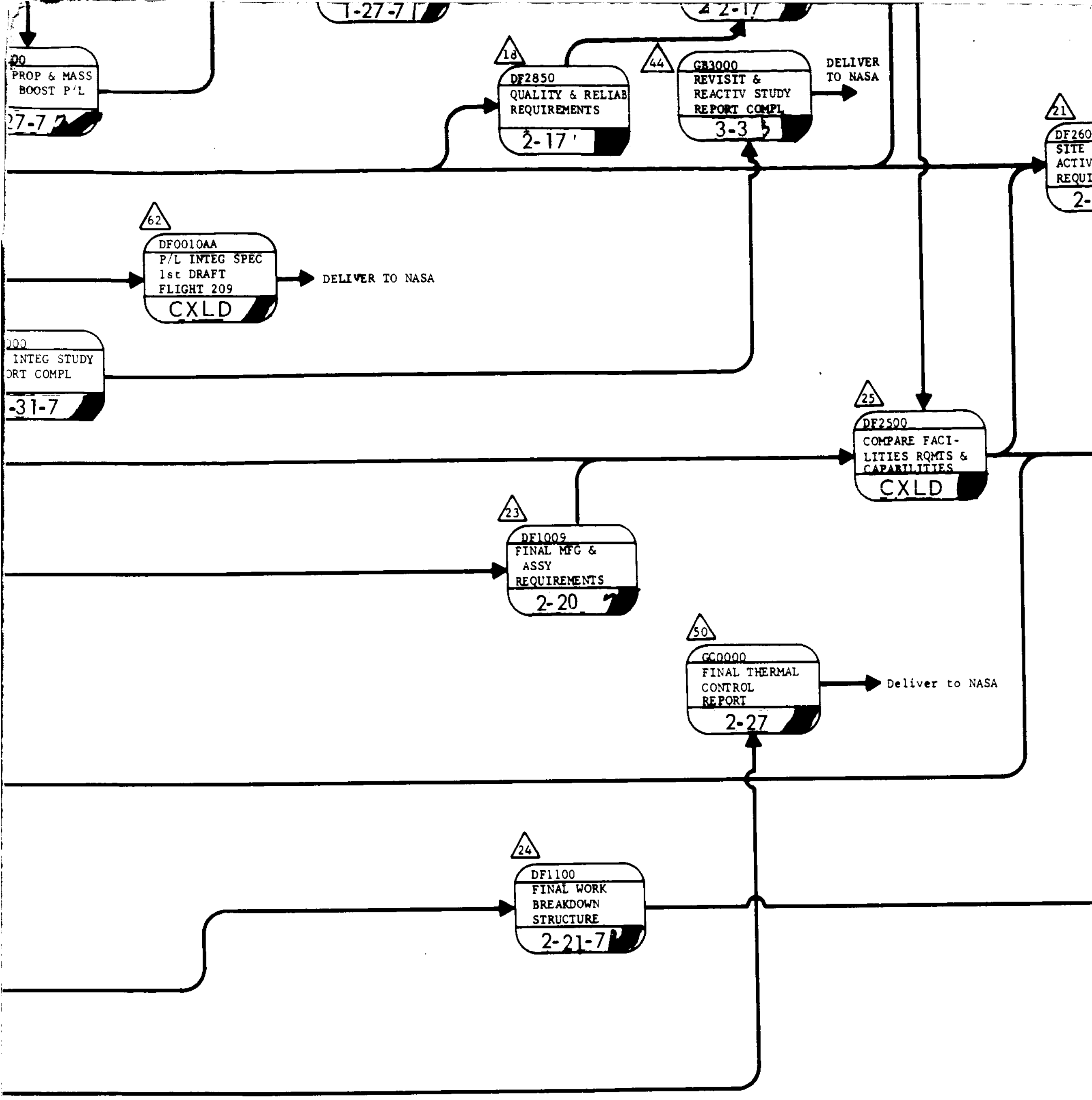

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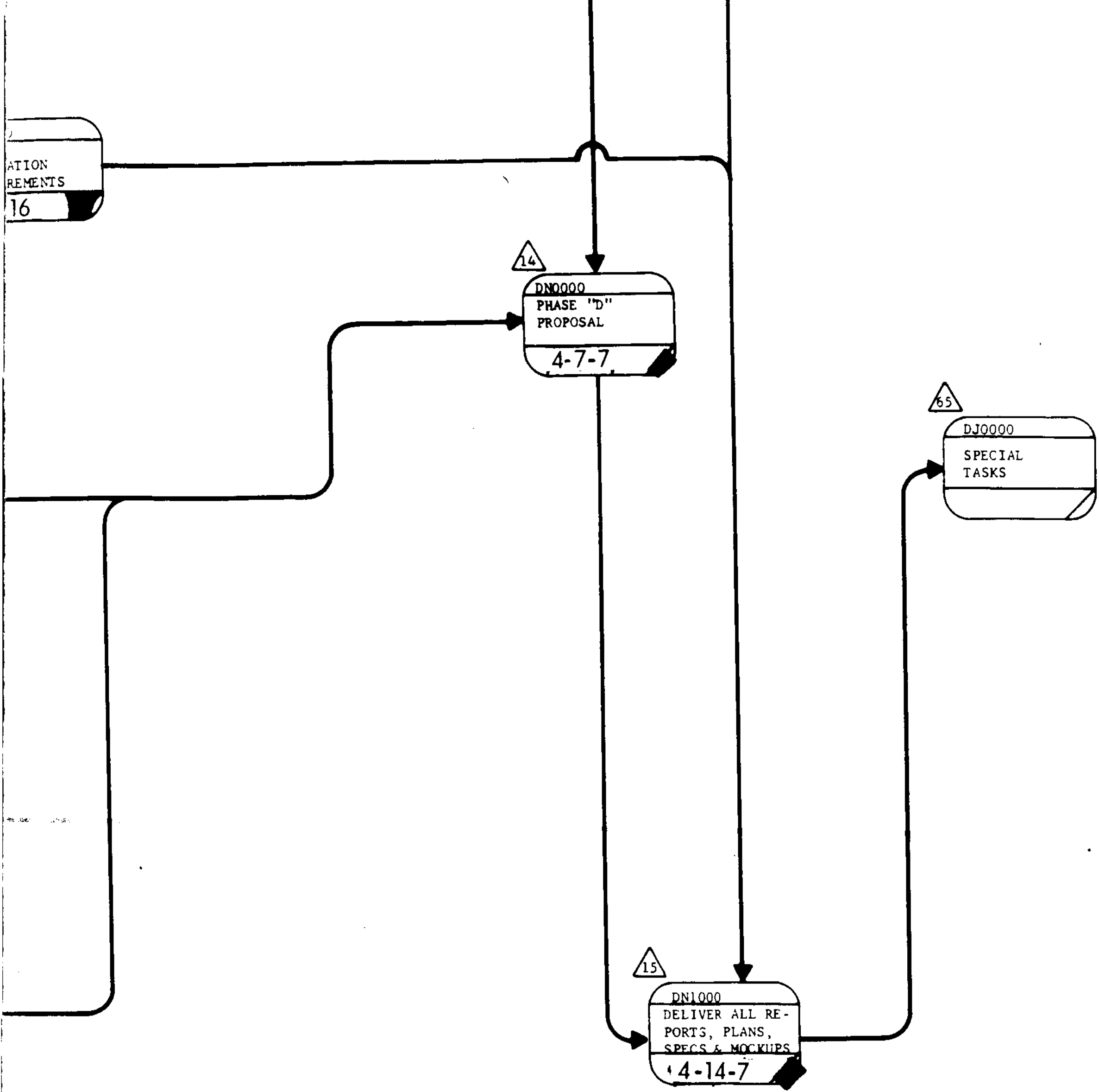

Figure I-1 AAP Phase C Activity Plan

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It will be extremely important to maintain close liaison with ATM experiment developers during their development and qualification test programs to minimize ATM integration alignment problems. Interface compatibility tests of the ATM rack with an LM/AS prototype will also be required to ensure proper control of the ATM can be achieved from the LM.

The flight ATM rack must be subjected to much the same test program as the prototype since minor manufacturing tolerance deviations could have a major effect on the flight system pointing performance. Our studies also indicate that the transportation environments will require that an alignment check also be made at KSC. Other launch site tests include an interface fit check of the LM/AS to an MDA simulator and performance evaluation checks of the Flight 4 spacecraft when integrated with a simulated cluster.

7. Phase D Proposal - The Test Engineering and Operations Group prepared technical input to five Phase D proposal documents. These were:

Cost Proposal	PL 2050
Technical Requirements Summary	PL 2052
Management Plan	PL 2053
Design and Development Plan	PL 2055
Technical Operations Plan	PL 2056

These five plans describe the functions we plan to accomplish for the AAP and indicate the degree to which we will phase into the current testing activity. Chapter VI of the Technical Operations Plan describes the test activities we will accomplish for the AAP after January 1, 1969. Section F of Addendums A and B to the Technical Operations Plan define the testing efforts that we plan to become involved in during this phase-in period.

8. Conclusions and Recommendations

a. Test Management - In view of the complexity of the integrated test program, and the number of agencies and manufacturers concurrently involved, it becomes mandatory that firm test management and control methods be developed. We recommend that a common test policy be adopted by all participants in the AAP test program. These policies are listed in Chapter VI of the Technical Operations Plan, PL 2056, and further expanded in the General Test Plan, Volume I, Test Program Summary.

We recommend that the test management and control methods described in the testing section, Chapter VI of the Technical Operations Plan, PL 2056, be used. We have developed and used these methods during the Titan I, II, and III test program with success. We recommend that studies be initiated in the area of test management to determine the adaptability of these basic methods to the AAP test program.

b. Studies - We recommend that in-depth studies be undertaken in the following areas:

Methods to determine and verify the accuracy of ATM-experiment/subsystem alignment;

Checkout methods for the ATM rack pointing control system;

Methods to accomplish system-level EMC checkout;

Methods of qualification of solar arrays on a system level;

Methods of handling, qualification, and acceptance checkout of late arriving experiments;

Evaluation of methods and the application of flight testing of AAP hardware, such as the S-IVB hydrogen tank for passivation.

c. Tests - We recommend that the following tests be performed relative to AAP 1/2, 3/4:

S-IVB passivation test be performed on an early Apollo flight to verify proper passivation;

Docking tests on every applicable carrier to be performed at KSC;

Cluster tests on AAP-1 and -2 using simulators or prototypes for AAP-3 and -4 elements at KSC, and cluster tests on AAP-3 and -4 using AAP-1 and -2 simulators or prototypes at KSC inasmuch as all AAP 1/2, 3/4 flight articles will not be concurrently available at KSC;

Mate and checkout of flight article LM/AS and ATM rack at KSC;

Preinstallation tests of the pointing control system (PCS) using a rate table;

Experiment alignment verification be performed on the ATM rack at MSFC and at KSC;

Fit checks of experiments into the MDA be performed at MSFC using prototype or simulators of the flight experiments being installed at KSC.

In support of these tests, we recommend that an LM/AS prototype be maintained at MSFC for flight ATM rack checkout. Master gages (mating parts) and certified AAP system interface simulators will also be required at MSFC and KSC.

C. RELIABILITY

Reliability engineering and assurance tasks completed during the Phase C Apollo Applications Program are summarized in this section. These tasks were accomplished to define the reliability aspects of the payload integration program and provided the basis for developing the reliability program plan described in Chapter VI of PL 2056, Technical Operations Plan, one of the Phase D proposal documents.

1. Reliability Program Definition - Functional roles were determined and assigned in three areas of reliability activity -- reliability program management, reliability engineering, and reliability assurance. These assignments were based on review of existing Apollo reliability programs, the Apollo Reliability and Quality Assurance Program Plan, NHB 5300.1, a preliminary draft of the AAP Reliability and Quality Assurance Program Plan, AAP mission requirements, and NPC 250-1. The results of these assignments are contained in Table VI-2.

Table VI-2 AAP Reliability Functional Relationships

RELIABILITY PROGRAM MANAGEMENT	RELIABILITY ENGINEERING	RELIABILITY ASSURANCE
● Provide reliability program interface between MSFC, AAP contractors, and other NASA agencies ● Implement the contractor's Phase D reliability program ● Establish methods for coordinating and integrating reliability analyses and FMECA ● Participate in crew safety and reliability program reviews	● Establish reliability requirements ● Review reliability program plans for MSFC AAP participating contractors ● Participate in design reviews ● Compile coordinated FMECA for each AAP mission ● Evaluate single-point failures and provide recommendations for design changes	● Monitor failure reports, failure analysis reports, corrective action summaries, and equipment logs for reliability problems ● Monitor test programs to identify failure modes detrimental to crew safety and attainment of mission objectives ● Compile reliability data for flight readiness reviews

The failure mode, effect, and criticality analysis (FMECA) was selected as the focal point for the AAP reliability program. This analysis results in the assignment of a criticality category to each article of AAP equipment, based on the impact of equipment failure on crew safety and mission objectives. Once established, the criticality category determines the scope of the reliability program and the extent of reliability requirements for each AAP component. In addition to serving as a classification system for failures, the criticality categories are used to establish critical part and component lists. These lists provide the basis for allocating test and quality assurance resources to critical equipment and for determining test and inspection levels and methods, and requirements for special handling. The criticality categories for flight hardware, including experiments, are defined in Table VI-3.

Table VI-3 Criticality Categories, Flight Hardware

Category	Definition
I	Any failure that will result in loss of life of any crew member
IIA	Any failure that will result in not achieving one or more primary mission objectives but does not cause loss of life
IIB	Any failure that will result in not achieving one or more secondary mission objectives, but that does not cause loss of life or preclude the achievement of any primary mission objectives
III	Any failure that does not cause loss of life or preclude the achievement of any primary or secondary mission objectives

The FMECA requires the active participation of each AAP contractor during Phase D. Consequently, we recommend that each AAP contractor contribute to the analysis in accordance with Table VI-4 by developing or updating FMECAs for equipment that is his design responsibility. After individual equipment FMECAs have been completed, a coordinated FMECA at the integrated equipment module is required to ensure that failure modes do not propagate across equipment interfaces and produce interactions between experiments and subsystems. The task of preparing a coordinated FMECA for each AAP flight is visualized as being the responsibility of the payload integration contractor.

Table VI-4 FMECA Activity

Item	FMECA Responsibility	Action Required
Experiment Carriers	Carrier Contractor	Prepare FMECA
Experiments	Experiment Developer	Prepare FMECA
Experiment Support Systems		
Existing Equipment in Carrier Baseline	Carrier Contractor	Prepare FMECA
Add-on Equipment Previously Qualified	Equipment Contractor	Update for AAP Application
Add-on Equipment Design and Development by Payload Integration Contractor	Payload Integration Contractor	Prepare FMECA
Add-on Equipment Design and Development by Other MSFC Contractors	Equipment Contractor	Prepare FMECA
Integrated Experiment Module	MSFC and Payload Integration Contractor	Prepare Coordinated FMECA

A single-point failure list can then be prepared from these analyses to focus attention on failures that lead directly to loss of crew or mission objectives. Recommendations for resolving critical failure modes are as follows:

1) Category I and IIA failure modes will be eliminated or reduced to low levels of probability through redundancy or other design approaches;

2) Category IIB failure modes will be made fail-safe to minimize their effect on the system if they cannot be eliminated or reduced to low levels of probability.

In Phase C, an analysis was undertaken to determine the reliability disciplines required for each article of hardware. Functions that would yield the greatest return in reliability improvement for a given investment of program resources were emphasized. The investment in reliability occurs in four areas:

1) Participation by Reliability in system, subsystem, and component design;

2) Promotion of design integrity through dissemination of reliability design criteria and standardization techniques;

3) Surveillance of design for compliance with reliability requirements;

4) Evaluation of reliability through test programs.

The recommended scope of reliability programs, based on the four categories of equipment criticality, is described in Table VI-5. FMECA, design review, qualification test programs, and failure reporting systems are fundamental to the reliability programs for all AAP equipment and will provide the basic data to minimize the propagation of failure effects.

Table VI-5 Reliability Disciplines vs Equipment Criticality

	Criticality of Equipment Based on FMECA			
	Category I	Category IIA	Category IIB	Category III
Participate in System, Subsystem and Component Design				
1. FMECA	x	x	x	x
2. Reliability Apportionment	x*			
3. Prediction and Assessment	x*	x†		
Promote Integrity of Design				
1. Standardization of Design Practices	x	x	x	x
2. Part and Material Selection	x	x	x	x
3. Reliability Training	x‡	x‡		
Survey Design for Compliance with Reliability Criteria				
1. Design Review	x	x	x	x
2. Design Spec Review	x	x	x**	
Evaluate Reliability of Design				
1. Reliability Test Program	x††	x††		
2. Qualification and Requalification test Programs	x	x	x	x
3. Failure Reporting and Corrective Action	x	x	x	x

*Emphasis on crew safety aspects of design.

†Reliability prediction accomplished in criticality analyses during FMECA.

‡Required for experiment hardware developers not previously exposed to reliabiltiy concepts.

**Accomplished during design review.

††Reliability test program in AAP is integral with qualification test program and is limited to failure modes detrimental to crew safety or primary mission objectives.

The promotion of design integrity deserves special attention by NASA and the payload integration contractor. This concept operates on the premise that design approaches, known from past experience to degrade reliability, should not be repeated in AAP.

It depends exclusively on the wealth of reliability information accumulated in NASA programs, past and current. For example, the NASA PRINCE/APIC data system provides a central clearinghouse for information on parts application. Experiment hardware developers must be encouraged to use this NASA service and thereby promote the scientific integrity of their equipment.

2. Phase C Program Support

a. Environmental Criteria - A catalog of natural and induced environments for each experiment carrier was prepared to provide environmental design criteria for top-level specifications, including the payload development specification, design reference mission documents, and the general design plan. During the carrier selection study, it was concluded that all candidate carriers were influenced to the same extent by the natural environments and required similar degrees of isolation and protection. The induced environments, principally temperature and vibration, are functions of equipment layouts and duty cycles, which, in turn, are highly mission-dependent. Continued development and maintenance of environmental criteria are mandatory in Phase D to ensure that test planning and qualification test levels are compatible with changing mission requirements.

Induced environments are subject to change when equipment locations are modified and experiments are added or deleted. Consequently, environmental criteria must be flexible and permit test of equipment within an envelope of environments including all potential applications.

b. Reliability Requirements - General reliability requirements were prepared and included in AAP documents and specifications in Phase C. Mission-oriented requirements for crew safety and mission success were defined for the cluster configuration, Flights 1 thru 4. Documents containing reliability requirements include the design reference mission documents, payload integration general specification, S-IVB workshop hardware requirements document, and the general design plan. Reliability personnel participated in a design review of these documents, subsystem design, and crew operations. As an outgrowth of the design review, a crew safety panel has been established under the direction of the Crew Operations Department with representation by Reliability.

c. Reliability Analyses - A failure mode and effect analysis was prepared for Flight AAP-2 and formed the basis for evaluation of hazards to crew safety. Recommendations for design changes to preclude Criticality I failure modes were presented to NASA in Report ED-2002-24. Subsequently, a similar analysis was conducted to support a compatibility analysis of the cluster configuration, Flights 1 thru 4. The objective of this analysis was to examine the functional design of the cluster and identify flight constraints. Workshop activation and reactivation sequences were identified as areas that require further study to eliminate hazardous crew operations. The details of this analysis are contained in ED-2002-48. Concurrent with reliability analyses performed in Phase C, a family of reliability models was developed for use in compatibility analysis. These models are described in ED-2002-84.

A. MANUFACTURING PLAN PREPARATION

The "manufacturing laboratory" approach was used in developing the manufacturing plan. This concept promotes the use of simplified procedures and tooling to support a development program yet emphasizes product integrity by employing controls at critical build points. Integral elements of this operating philosophy are the ability to rapidly react to program changes and to achieve versatility through available facilities:

1) On-the-spot technical support in the form of Engineering, Test, and Quality personnel located adjacent to the installation area will provide the rapid reaction to program changes;

2) The many facilities made available for this program to provide manufacturing versatility include,

    a) Payload integration facility at MSFC for AAP payload integration,

    b) Other MSFC facilities on a noninterference basis,

    c) The payload integration contractor's Huntsville off-site facility,

    d) The Martin Marietta, Denver division, facility,

    e) The Bendix off-site facility,

    f) The Bendix-Teterboro facility,

    g) Huntsville area subcontracting sources.

The AAP missions were analyzed to identify manufacturing tasks. Carrier modification, experiment installation, experiment support system fabrication and installation, and ground support equipment are the principal areas of activity. Special test equipment, special tooling, mockups, and training aids are categorized as manufacturing activities that support the primary tasks. The fabrication of a mission configuration design verification fixture using full-scale flight-configured prototypes or simulators was proposed to verify manufacturing and test operations.

Manufacturing support is also provided by control functions, i.e., material and equipment accountability, scheduling, pack and ship operations, and conservation. These personnel perform the scheduling, expediting, and stockroom functions. We have selected a short-order system approach to coincide with the manufacturing laboratory technique.

The Manufacturing Engineering section of our plan describes the preplanner's functions and promotes the use of soft tooling. In addition to the tool design and process planning activities, an Advanced Manufacturing Technology section will be available to determine if new processes are required or if existing processes need revising.

B. MANUFACTURING OPERATING PROCEDURES

Several field trips provided information pertaining to MSFC operating procedures and facility capabilities. Martin Marietta procedures were reviewed for compatibility with MSFC operations. We plan to continue this process to ensure that existing internal procedures are reviewed and revised, as appropriate, before Phase D contract go-ahead.

C. MOCKUP ACTIVITIES

Area requirements for mockup development, fabrication, and display were identified and made available to support the mockup program during the Phase C effort. The completed mockup area with the adjoining shop and conference room is shown in Figure VII-1.

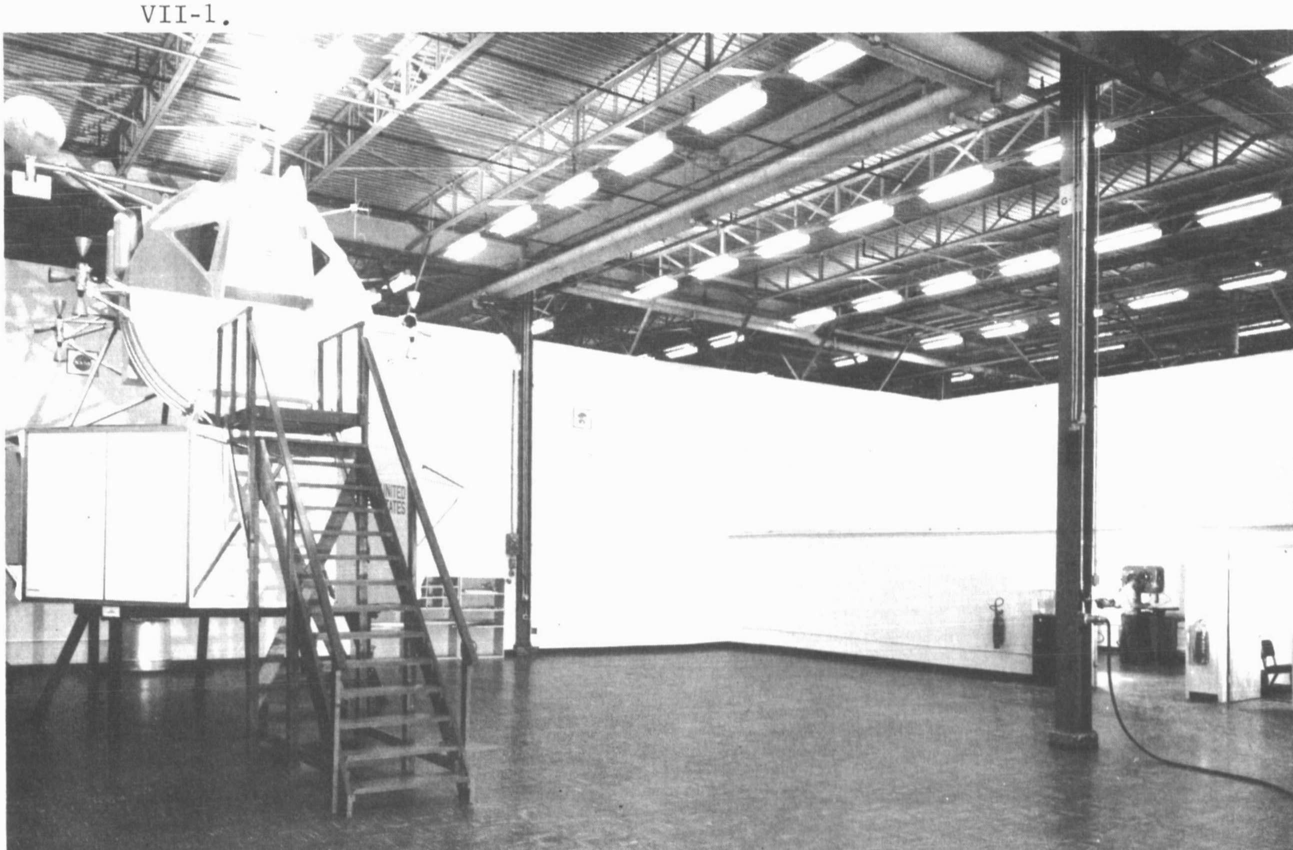


Figure VII-1 Mockup Area

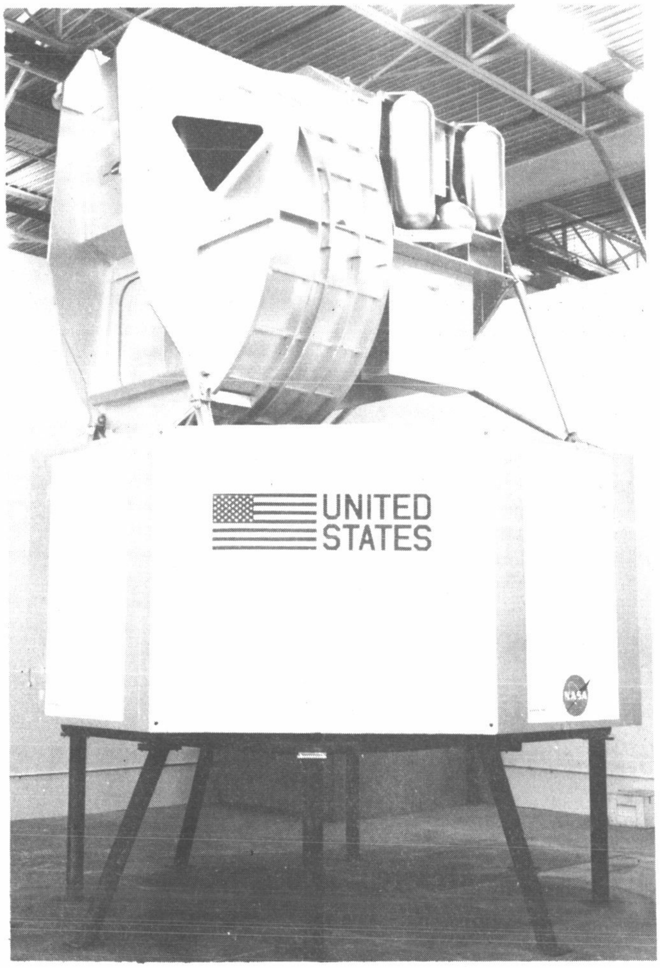


Figure VII-2 LM Mockup

1. LM Mockup - Mockup activity during Phase C began with the receipt of the LM mockup from MSFC July 25, 1966. The mockup components were identified and accountability records established. Each of the mockup components was refurbished, assembled, and erected as shown in Figure VII-2.

2. Full-Scale Cluster and Other Mockups - During Phase C we have constructed various 1/10-scale models and full-scale mockups of the various AAP carrier vehicles and the total cluster that evolves from Flights AAP-1 thru -4. Engineering personnel have used these models and mockups during the conceptual study phase of the contract as three-dimensional layout tools to determine the physical configuration and mounting arrangements of the experiment packages and subsystem add-on components on the various carrier vehicles. The full-scale mockups have been used by the crew activity designers to determine EVA and crew station procedures, mobility aids, and umbilical locations. The full-scale mockup of the cluster is shown in Figure VII-3.

This configuration consists of the following vehicles with experiment packages and subsystem components mounted thereon:

1) CM;
2) MDA;
3) AM;
4) SLA;
5) IU;
6) Forward dome of S-IVB tank;
7) Resupply rack;
8) LM ascent stage;
9) ATM rack.

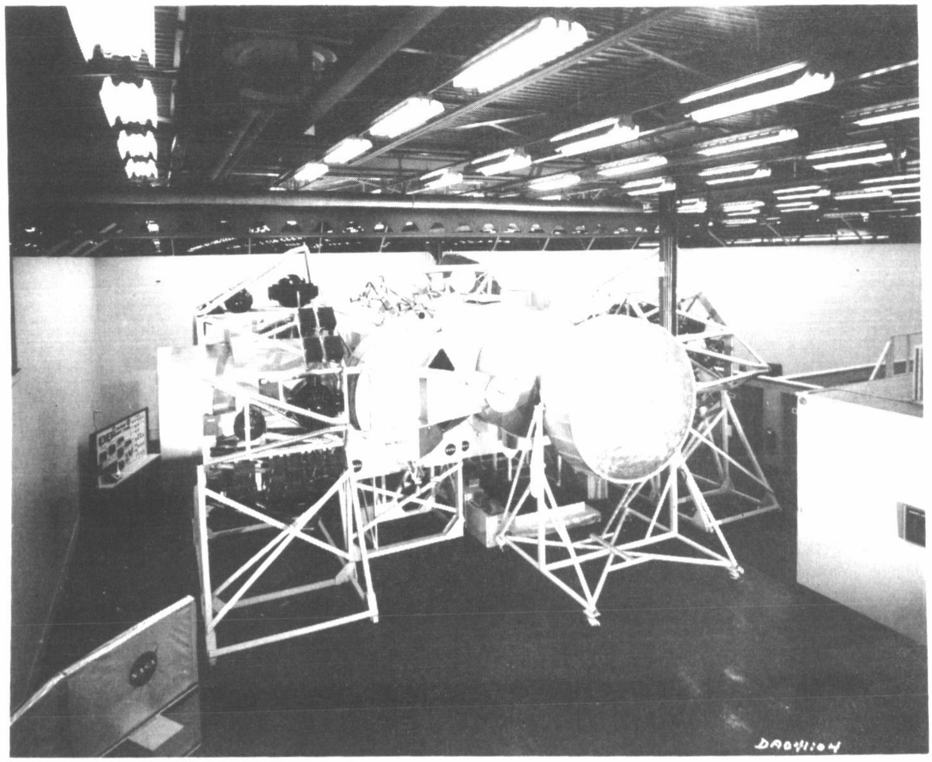


Figure VII-3 Full-Scale Cluster Mockup

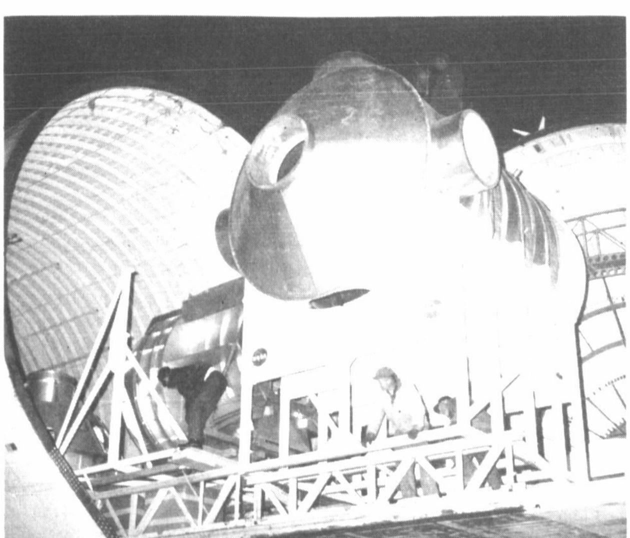


Figure VII-4 MDA Loading for Airlift

This full-scale cluster configuration was assembled in January 1967 at the Martin Marietta facility at Denver, Colorado. The mockup was displayed during the NASA program review held January 26, 1967.

In March 1967, as requested by NASA, the full-scale cluster mockup was disassembled and transported to MSFC. Figure VII-4 shows the MDA being loaded for airlift to MSFC. At MSFC the full-scale cluster mockup was reassembled for display in Building 4755, as shown in Figure VII-5.

In addition to the full-scale cluster mockup, components and other models and mockups were completed during the second contract period.

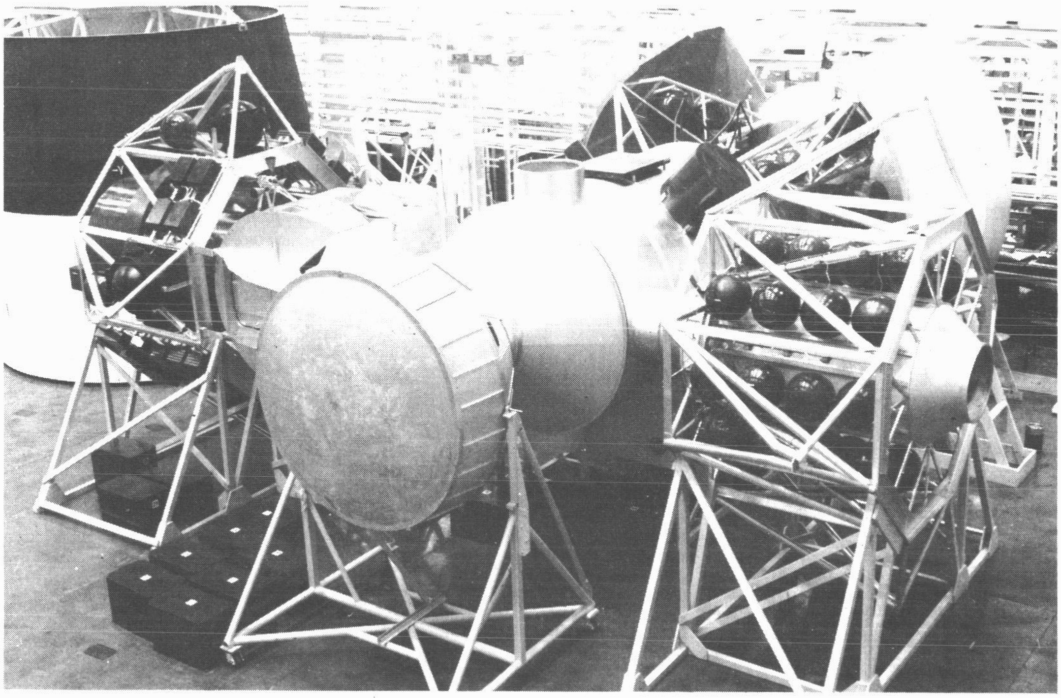


Figure VII-5 Full-Scale Cluster Mockup on Display at MSFC

The 1/10-scale models that have been constructed include the following specific configurations:

1) CSM;
2) MDA;
3) AM;
4) S-IVB external configuration with solar arrays;
5) S-IVB orbital workshop internal configuration;
6) EO-2 rack;
7) Project Thermo rack;
8) ATM-1 rack;
9) LM ascent stage;
10) LM descent stage;
11) SLA;
12) IU;
13) RCM;
14) LM&SS rack;
15) Total cluster (using above components) with solar arrays.

In addition, three 1/20-scale models were made during the initial studies of the cluster using various boom structures to support the ATM at a distance from the S-IVB orbital workshop.

Various full-scale mockups were also made and tested in such crew activity studies as:

1) Sealing of such S-IVB tank penetration points as LH_2 suction line and screen, LH_2 chill pump, fill and drain line;
2) Cargo transfer methods;
3) Mobility aids.

Models of four quick-release fastener concepts were made and tested.

A. ORGANIZATION

The initial AAP definition phase organization is shown in Figure VIII-1. Minor changes were made in the structure as we gained a better understanding of the tasks to be accomplished. These changes are reflected in Figure VIII-2 which portrays the organization used for the conduct of the effort for the second contract period of the Phase C contract.

Changes in organization occurred as follows:

1) The training and logistics functions were combined under the Industrial Resources Department and the test and launch operations were combined under the Quality Department;

2) The Crew Operations organization was restructed; four major areas of activity were identified,

   a) Human factors and task analysis,

   b) Astronaut Training,

   c) Flight operations and crew safety,

   d) Simulation and special tasks.

The Bendix Corporation, as the major subcontractor, provided specialized experience and knowledge in certain categories of experiment types, subsystem design, and general support to the Martin Marietta Corporation. Martin Marietta provided overall program management and system responsibility. The effort expended by Bendix was integrated with the Martin Marietta effort. A parallel organization established by Bendix permitted direct communication with Martin Marietta counterparts of all levels of organization as shown in Figure VIII-3. Bendix-assigned personnel were physically located in the AAP area of the Martin Marietta plant in Denver.

These areas of Bendix Corporation responsibility were:

1) Analysis of specific experiments in the general fields of astronomy, communication and navigation, remote sensors, and lunar surface;

2) Subsystem responsibility in the areas of flight communications; ground networks; displays and controls; and guidance, navigation, and control;

3) Technical support of Martin Marietta in the areas of mission analysis, integration of experiments, facilities, management analysis and planning, functional requirements and planning, and development of mockups.

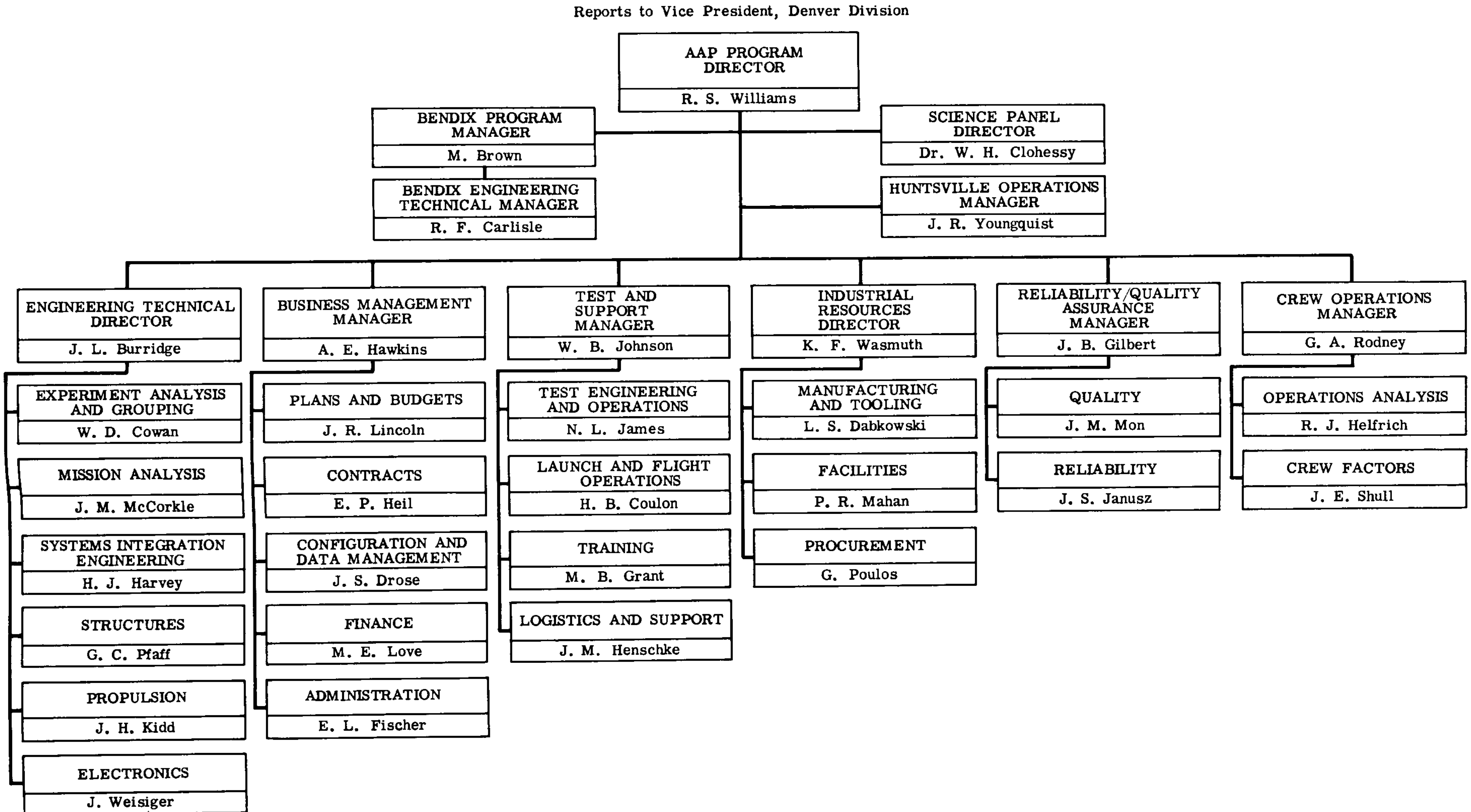
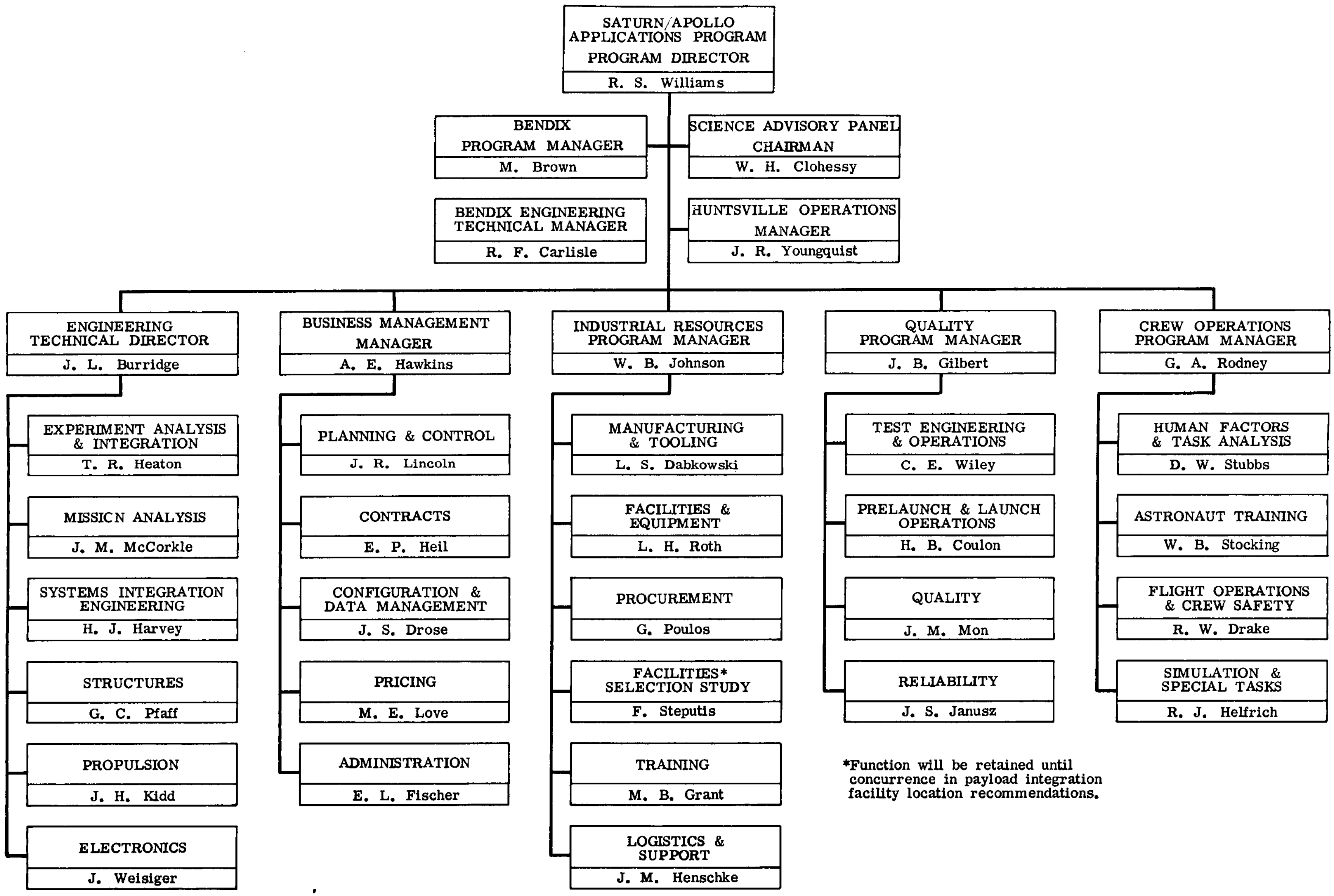


Figure VIII-1 Initial AAP Project Phase C Organization



*Function will be retained until concurrence in payload integration facility location recommendations.

Figure VIII-2 Current AAP Project Phase C Organization

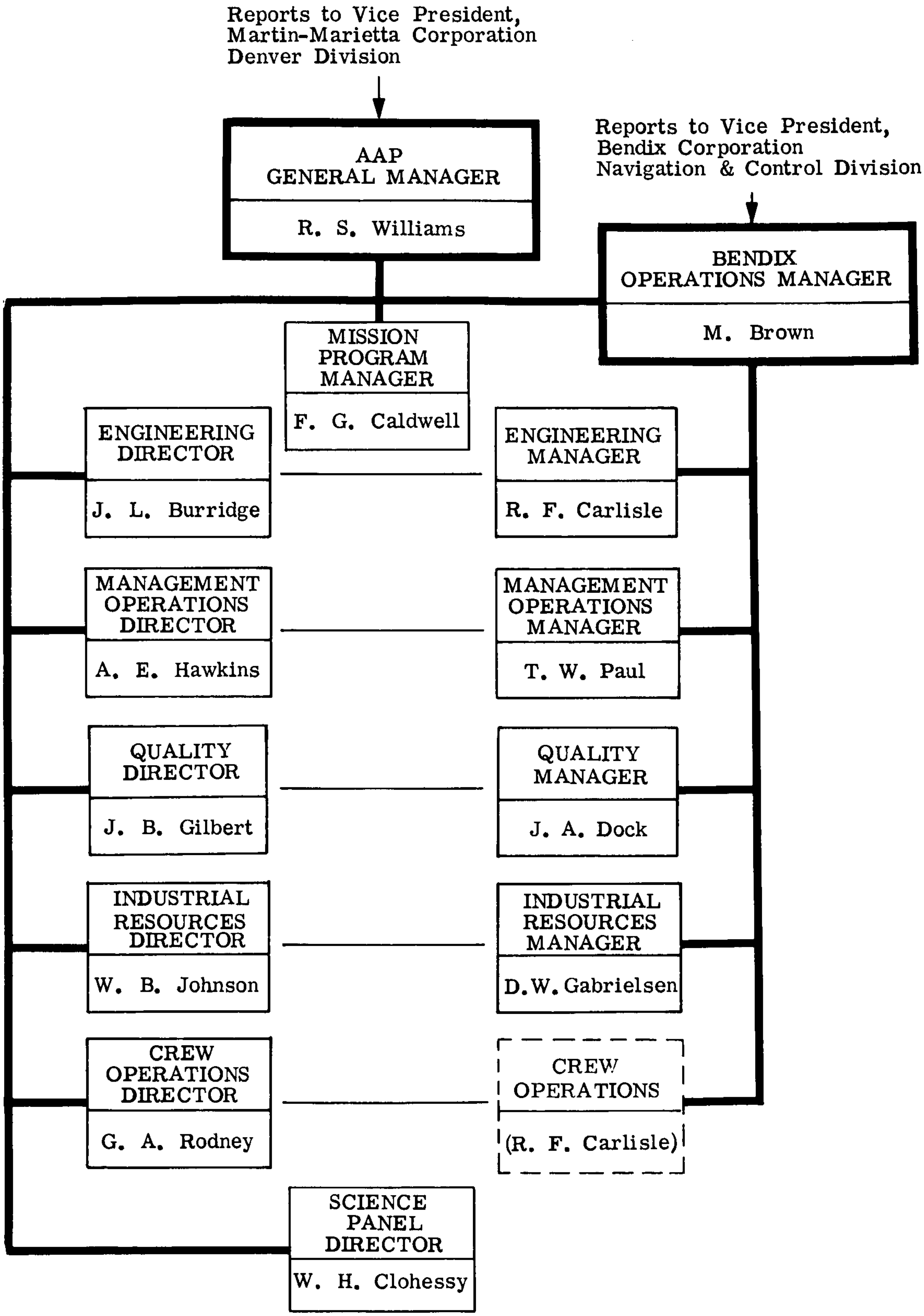


Figure VIII-3 Martin Marietta/Bendix Organizational Relationships

B. PROGRAM MILESTONES

During the six-month contract period ending 7 April 1967, the contractor's efforts were focused on the following tasks:

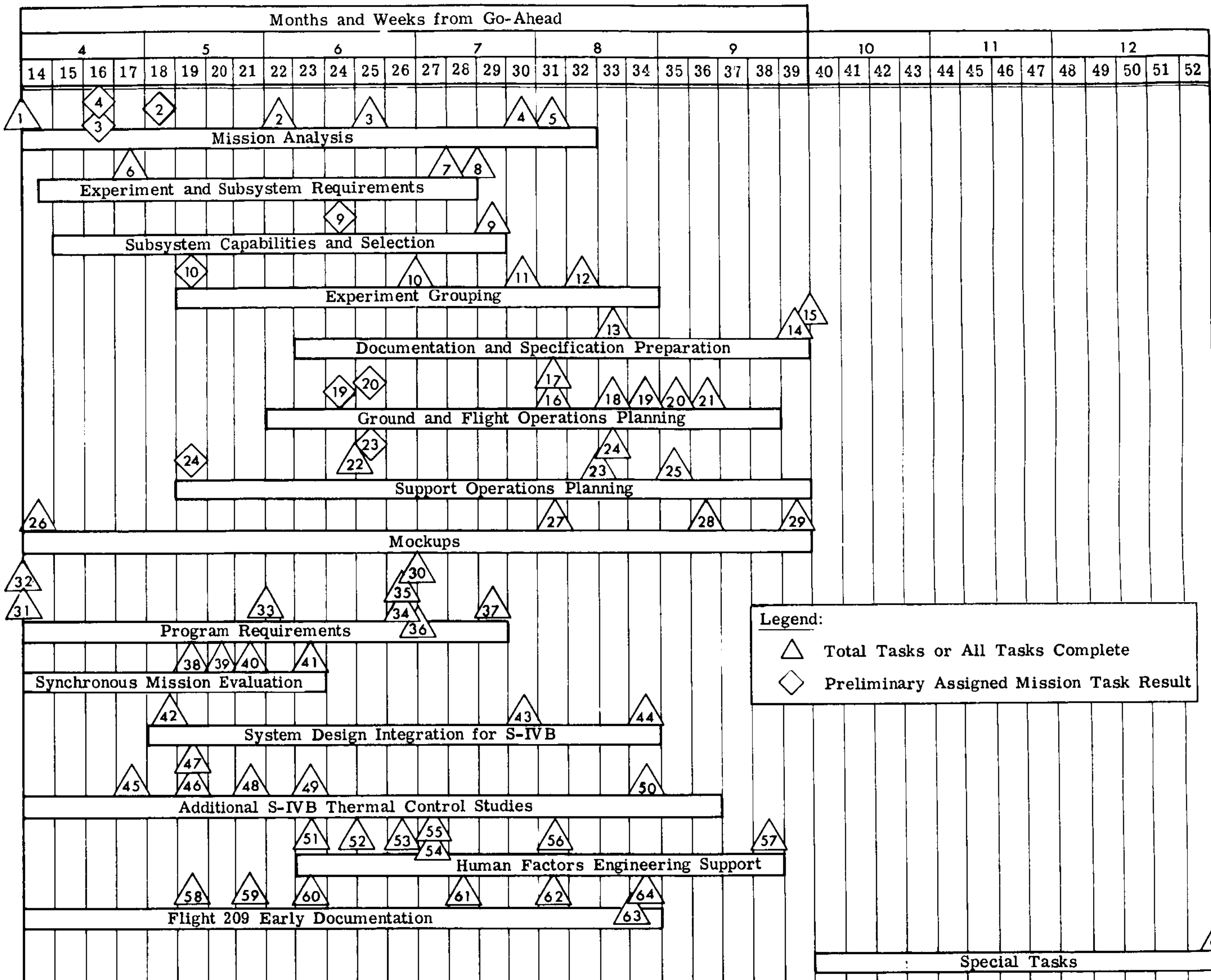
1) Support of the propulsion and vehicle engineering (P&VE) laboratory on the S-IVB workshop;
2) Analysis and definition of the assigned mission;
3) Analysis of experiments suitable for synchronous missions;
4) Preparation of plans and a proposal for the Phase D activity;
5) Technical support.

Early in October, 72 milestones considered critical to the successful completion of this second contract period were developed. These milestones included preliminary and final completions of tasks shown in the Definition Phase Program Plan, PL 2001 Rev A, 3 November 1966. The AAP summary planning network, Figure I-1, displays these milestones and the time when each milestone was completed. This network was used for graphic presentation of the program status in the project control room and the Denver management control room. Of these milestones, eight were canceled by project concept adjustments. These milestones are shown in Figure VIII-4 and the milestone event status chart, Figure VIII-5 shows the contractor's performance of the project during the second contract period.

The plan line represents the cumulative number of milestones to be completed through each week. The solid line represents actual milestone completions. As indicated by the chart, the project remained on schedule through November, falling one milestone behind schedule during the first week in December 1966. From the second week in December through the end of Phase C, the project performed on or ahead of schedule. Program management emphasis in February and March was directed toward preparation of planning data which contributed to the Phase D proposal.

During the contract period extending from October 1966 through March 1967, six modifications to the contract were received. Modifications 2 and 4 were administrative changes; Modification 3 revised Exhibit C, Documentation Requirements for Definition Phase; Modification 5 added 10 tasks under the Special Tasks Clause; and Modification 6 added Special Task 11 covering definition of external contamination detection equipment.

During the last three months of the Phase C contract we will be engaged in performance of special tasks which were assigned by Modification 5 to the contract. The schedule for accomplishment of these tasks is shown in Figure VIII-6.



GLOSSARY OF MILESTONES

1. First Period Requirements & Capabilities Established
2. Specific Mission Functional Analysis
3. Refined Mission Analysis
4. Refined Trajectory Analysis
5. Final Integrated Timelines
6. Experiment Requirements Defined
7. Subsystem Requirements (Final)
8. Operations Profile & Crew Task Requirements
9. Final Subsystem Selection
10. Final Experiment Grouping
11. Geo Prop & Mass Char Booster Payload, Spacecraft
12. Final Configuration Drawings
13. Final DRMD
14. Phase D Proposal
15. Deliver All Reports, Plans, Specification, & Mockups
16. Launch Operations Support
17. Flight Operations Support
18. Quality & Reliability Requirements
19. Final Test Requirements
20. Final GSE Requirements
21. Site Activation Requirements
22. Submit Cost Format Recommendation to NASA
23. Final Manufacturing & Assembly Requirements
24. Final Work Breakdown Structure
25. Compare Facility Requirements & Capabilities
26. Begin Mockup Use
27. Assigned Mission Mockup Preliminary
28. Mockup in Final Configuration
29. Mockup Available
30. Direction from NASA on Assigned Carriers
31. Initial Experiment Requirements & Assignments
32. NASA Designation of Assigned Missions
33. Assignment of Second Mission (NASA)
34. Final Mockup Configuration Instructions from NASA
35. Payload Integration Facility Location Decision (NASA)
36. Phase D Proposal Instructions from NASA
37. Cost Data Format Approved (NASA)
38. Final Experiment Data Prepared
39. Schedule Model Verification
40. Final Experiment Selection Complete
41. Deliver Report
42. Activation & Assembly Study Report Complete
43. Experiment Integration Study Report Complete
44. Revisit & Reactivation Study Report Complete
45. Frost/Condensate Preliminary Report Complete
46. Preliminary Report Meteoroid Shield
47. Preliminary Report Astronaut Comfort
48. Preliminary Study Report on Active Thermal Control
49. Preliminary Report on Temperature Gradient Study
50. Final Thermal Control Report
51. Workshop Passivation & Activation Task Analysis
52. Experiment Assembly Operation & Storage Task Analysis
53. Workshop Subsystem Operations Task Analysis
54. Crew Safety Analysis of EVA & Workshop Operations
55. Human Engineering Test Program Plan
56. Preliminary Crew Support Equipment Design Specifications
57. Flight Crew Training Reports
58. Design Reference Mission Document, Flight 209
59. Design Plan, Flight 209
60. Payload Development Document, Flight 209
61. Facilities Plan, Flight 209
62. Payload Integration Specification First Draft, Flight 209
63. General Test Plan, Flight 209
64. Subsystem Development Test Plan, Flight 209
65. Special Tasks

Figure VIII-4 Program Milestones, Second Contract Period

PR 2003-3

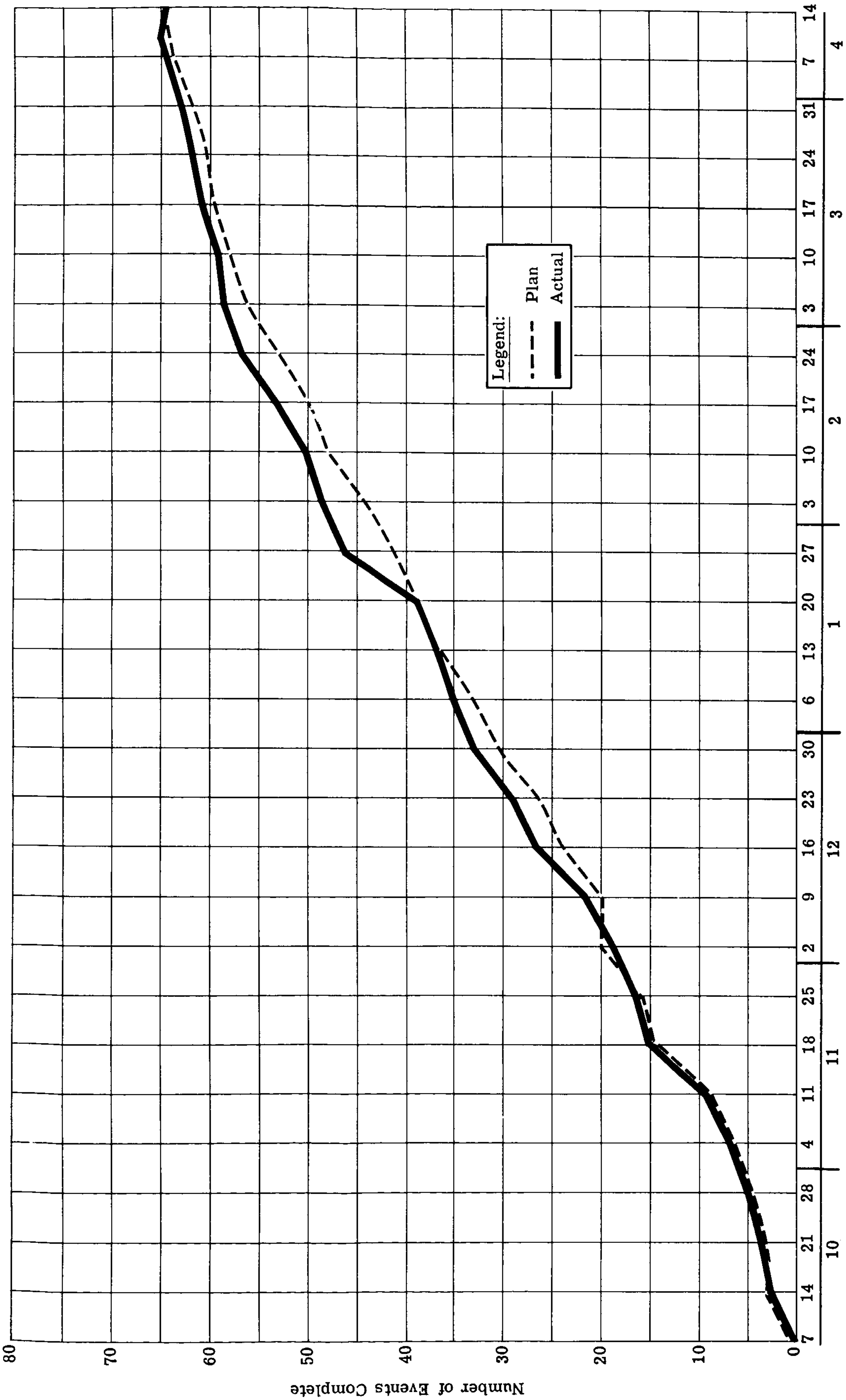


Figure VIII-5 AAP Milestone Event Status

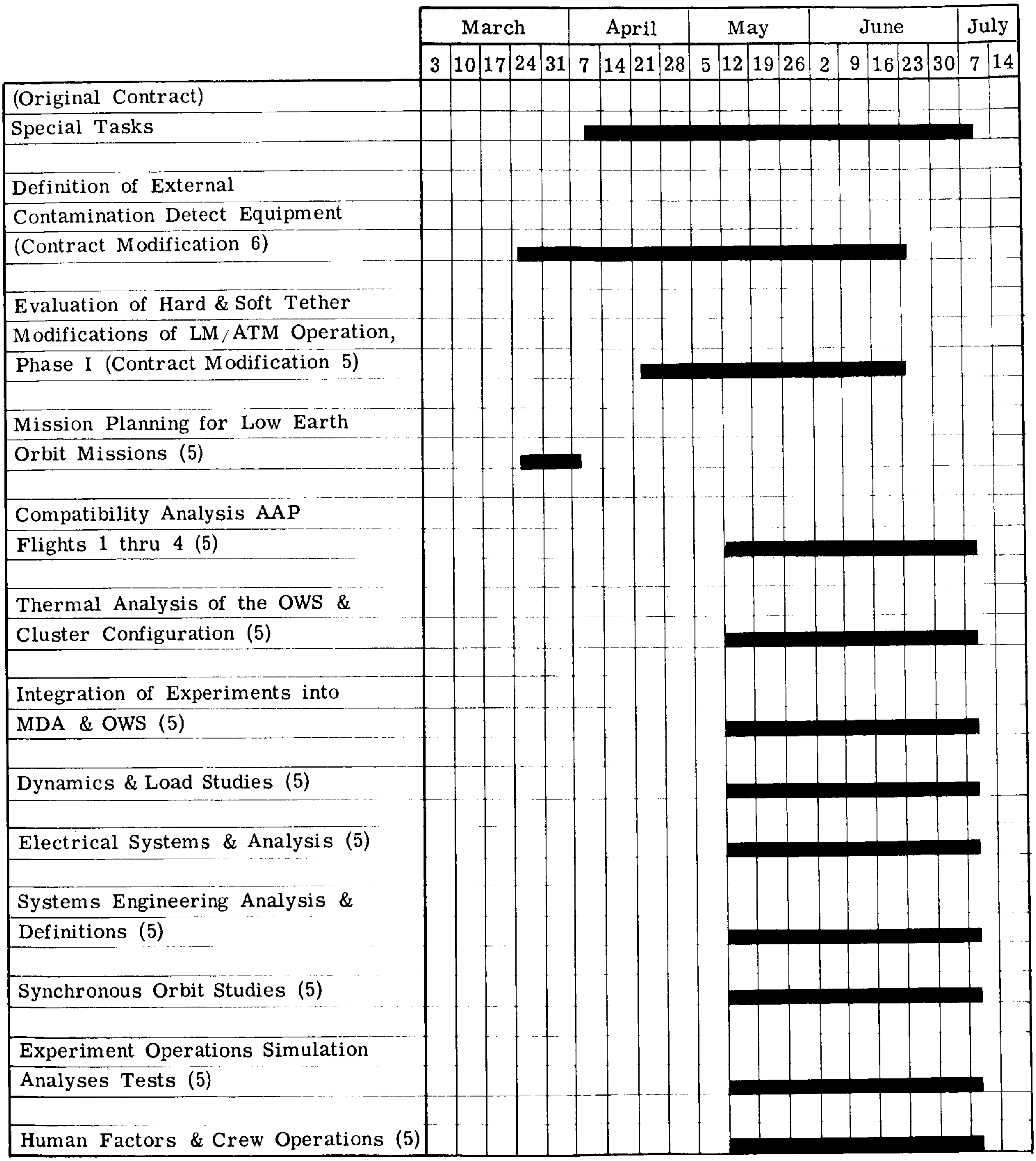


Figure VIII-6 AAP Phase C Final Contract Period

C. MANAGEMENT CONTROLS

1. Scheduling Activities - Control of the contractor's Phase C operation was maintained through use of routine techniques that include mechanized schedule control.

Detailed schedules were established early in October for all documents to be prepared during the second (six-month) contract period. Detail task plans were prepared by each department on the AAP Project describing all tasks that its organization would perform during this contract period. Task descriptions and work schedules were adjusted to reflect the various tasks and schedules associated with the assigned mission and the synchronous orbit mission analysis and to show the special tasks in support of P&VE on the Orbital Workshop.

Each detailed task was scheduled and the responsible organization identified. Task completions were transmitted to a computerized schedule system. Reports generated by this system showed status-by-task, status-by-organization, tasks to be completed in the next week, and delinquent tasks.

Detailed planning event-oriented networks were prepared for the assigned mission and related program requirements. These networks indicated the time when each activity generated a useful result. These networks were used as a graphic display of the AAP Project's program performance.

Deviations from schedule were noted in the weekly program status report and corrective action was directed by the Program Director at the weekly program review meeting.

2. Cost Control - A mechanized cost-collection system was used to provide cost status and control. Preprinted time cards for each task were used by the responsible organizations to provide inputs to the computer. Weekly reports of labor costs were analyzed, deviations from the budget noted, and corrective action taken.

3. Phase D Planning - The work breakdown structure (WBS) for the AAP Phase D payload integration contract was established incrementally during this contract period. Based on this WBS, the Martin Marietta AAP organization prepared detail task plans for each applicable task shown on the WBS. The WBS was then adjusted to coincide with the statement of work (SOW). Upon receipt of proposal instructions from MSFC, the WBS and SOW were revised to comply with these instructions.

The WBS was issued and detail task plans were prepared in conformance with the WBS and SOW. The Detail Task Plans were coordinated and prepared for a computer printout by WBS task and organization. These tasks provided the details used in preparing the Phase D cost estimates.

A. THERMAL BALANCE

Several areas have been investigated pertaining to thermal balance. These include:

1) Thermal and humidity control;
2) Thermal vacuum chamber test support;
3) Crew comfort criteria;
4) Temperature gradients;
5) Active thermal control systems.

1. OWS Thermal Control and Humidity Control Analyses - The objectives of these tasks were to perform thermal analyses on the hydrogen tank of the spent S-IVB stage to establish a preliminary design for an orbital workshop (OWS), and to determine if the minimum humidity could be maintained depending only on the human water production rate. The results of these efforts are documented in:

1) Analysis of Effect of Meteoroid Shields on Thermal Balance, ED-2002-8, November 15, 1966;
2) A Study of Condensation within the S-IVB Spent Stage, ED-2002-9, November 21, 1966;
3) Additional Thermal Control and Condensation Studies, S-IVB Spent Stage, ED-2002-20, January 5, 1967;
4) S-IVB Orbital Workshop Thermal Control and Humidity Study, Interim Study Report, ED-2002-47, February 8, 1967;
5) Feasibility Study, S-IVB Spent Stage Thermal Control Study, ED-2006, September 30, 1966;
6) Problems Associated with Condensation within the S-IVB Spent Stage, ED-2007, November 3, 1966;
7) Preliminary Thermal Analysis, S-IVB Spent Stage, September 9, 1966;
8) Final Thermal Control Study Report, ED-2002-39, March 1, 1967;
9) Additional Humidity Data, December 1, 1966;
10) Digital Computer Program for the Study of Condensation within the S-IVB Orbital Workshop, February 8, 1967;
11) Forward and Aft End Heat Leaks, S-IVB Orbital Workshop, ED-2002-74, March 22, 1967.

The following subtasks were undertaken to arrive at the current thermal control concept:

1) Preliminary studies of the effects of emissivity, orbit parameters, internal power, and sidewall film coefficient on the OWS environment;
2) OWS preliminary design studies based on results of the above studies;
3) Influence studies for optimizing the OWS preliminary design;
4) Determination of the equilibrium specific humidity and the thickness of the frost or water condensate when using the flow rates and temperatures that were determined from the thermal control studies.

The studies concluded that for the orbit conditions studied, wall, curtain, and atmosphere temperatures can be maintained within allowable limits by the proper use of fans and surface preparations; humidity limits can be maintained in excess of the minimum allowable while maintaining acceptable internal OWS temperatures; and the aft and forward outside ends of the OWS should be insulated with about ¼ inch of superinsulation.

2. Orbital Workshop Thermal Vacuum Chamber Test Support - The primary objective of the study entitled, Orbital Workshop Thermal Control Test Considerations in a 1-G Environment, was to determine what effects a 1-g environment will have on test results in comparison to the zero-g case, and if relevant data can be obtained in such tests.

The thermal control system selected for the S-IVB OWS depends on forced convection in transferring heat from the atmosphere to the tank walls. Several areas in this test would be affected by natural convection that is not present in orbit. These are in the ducts and along the inside curtain walls. The study analyzed effects of test article orientation (vertical and horizontal). Duct flow direction was studied to determine the effects of air flow over the hot and cold walls.

It was determined from the study that a useful thermal vacuum chamber test of the OWS could be performed. The best orientation was determined to be vertical with the duct flows in the same direction as used in orbit (referenced from top to bottom).

3. Crew Comfort Criteria - The following reports were submitted for studies made of crew comfort criteria:

1) Definition of Crew Comfort Requirements, ED-2002-7, November 15, 1966;
2) Appendix B of Definition of Crew Comfort Requirements, December 12, 1966;
3) Crew Comfort Definition at Various Metabolic Rates, December 14, 1966;
4) Comparison of Martin Marietta and NASA Computer Programs for Metabolic Analyses, February 9, 1967.

The purpose of the studies was to define the criteria (atmosphere, temperature, velocity, humidity, wall temperatures, etc) that create a comfortable shirtsleeve zero-g astronaut atmosphere. The problem of defining crew comfort conditions is complicated by the fact that a large number of variables need to be treated and test data, for the region of interest, are inadequate. Variables that need to be considered are metabolic rate, body area, vehicle acceleration level, ventilation rate, clothing thermal resistance value, clothing emittance, humidity, wall temperature, atmosphere temperature, atmosphere composition, and pressure.

Ventilation velocities from 5 to 320 fpm were studied. Values of clothing thermal resistance were allowed to vary from 0 to 4 while clothing emittance was assumed to be 0.8. Because of the similar properties of oxygen and nitrogen, the results of this task should not vary appreciably for a nitrogen-oxygen mixture at the same pressure (5 psia).

It can be concluded that an astronaut must have reasonable crew comfort limits (temperatures, humidity, air velocity, etc) in a zero-g shirtsleeve environment, and that these are not materially different from those found at 1-g. The primary difference is that the natural convection occurring on earth must be compensated for in an orbiting spacecraft by forced convection cooling and radiation to walls, clothing, etc.

4. Atmosphere Temperature Gradients in the S-IVB - This study was documented in ED-2002-19, Determine Atmosphere Temperature Gradients in the S-IVB Orbital Workshop, December 15, 1966. The objective of this study was to determine temperature gradients in the workshop atmosphere. If the temperature gradients are large, the astronauts will feel uncomfortable. An overall temperature gradient created by the ΔT required to absorb heat will exist in the workshop whether the thermal control system is active or passive.

Since the temperature gradients will be minimum if optimum atmosphere distribution is obtained, analytical effort was concentrated on the following distribution problems:

1) Study of fan performance;
2) Influences of diffusers on temperature distribution;
3) Location of fans within the workshop;
4) Defining a test plan for determining workshop atmosphere distribution.

The performance characteristics of the fans to be used for atmosphere circulation were calculated. After considering these characteristics along with the crew comfort criteria, it was determined that diffusers will be necessary in the personal hygiene area and living quarters. Three atmosphere distribution schemes were devised to be tested for determination of the best distribution system.

5. Thermal Control System Concepts - Studies of thermal control systems were documented in ED-2002-10, Active Thermal Control System for the S-IVB, and Addenda, Active Thermal Control System for the S-IVB, January 4 and 30, 1967.

Several concepts to actively control the thermal environment in the S-IVB OWS were studied. These concepts were aimed at providing an active thermal control system for the OWS with greater flexibility to control the atmosphere than can be obtained with the fan/duct system. A design objective of the study was to use existing systems and components wherever possible. The active systems in the instrument unit, the airlock module, and the command and service module were therefore considered.

The concepts considered were:

1) Use of the IU/S-IVB cold plates for S-IVB thermal control;
2) Use of excess radiator capability in the Gemini retro-adapter;
3) Addition of the Gemini equipment adapter radiator to the AM;
4) Use of excess water from the CSM for S-IVB cooling (water boiler located in the S-IVB);
5) Use of all the heat-rejection capability in the CSM;

6) Use of the supplemental cooling capability of the gas purification module for local cooling in the OWS;

7) Radiators installed on the SLA panels;

8) Use of the meteoroid shield as radiating surface.

Of the above concepts, 1) and 2) appeared to have promise and were studied in more detail. The study showed that there are no easy methods of adapting existing systems or creating new systems for temperature control of the OWS. Temperature control problems are similar with the active and the fan/duct system. Also, the active systems are more complex and could add operational problems. If an active system is necessary, it is recommended that the MDA radiator be sized and heat exchangers be added to the AM fluid circuit to condition the OWS. This appears to be the least complex of the schemes studied.

B. ORBITAL WORKSHOP ACTIVATION

Several studies were accomplished pertaining to the activation of the OWS. These studies and their reports are summarized in this section.

<u>1. Sequence Analysis</u> - A study was made and documented in ED-2002-6 to display and analyze a sequence of activities required to activate the orbital workshop. These analyses are intended to assemble data that may be used as a starting point for formal functional analysis, human factor studies, and hardware design considerations. The activation sequence extends to sufficient depth to provide a source of criteria as well as an accumulation of requirements for tools and supporting equipment. In addition, pertinent assumptions and required S-IVB prelaunch modifications are itemized.

The sequence of activities extends from the time liquid hydrogen tank entry is to be effected until the completion of the tasks to make the tank a habitable workshop, including the sealing of penetrations and the assembly and erection of all equipment and partitions for crew quarters, but not including activation of the corollary experiments.

This report and Revision A were submitted November 14 and December 30, 1966, respectively. In view of subsequent ground rule and configuration changes, this report will be updated and submitted in final form April 28, 1967.

2. Quick-Release Fasteners - Standardized methods for attaching the experiment packages that can be used in both stowed and deployed positions and that promised ease of operation for the astronaut were investigated and evaluated. This study was documented in ED-2002-12. A literature search was performed to locate a number of fastening devices that appeared to offer ease of operation, high reliability, minimum volume, and, to a lesser extent, low weight and cost.

The following fasteners were chosen for evaluation: over dead center, pip pin, trigger release with guide track, rotary breech lock, tapered slide in tapered receptacle, 360-degree turn-to-release structural cam-lock type, and door latch type with pip-pin retainer.

Experiment packages with these fasteners were mocked up for astronaut zero-g simulator testing. Results of these tests are documented in ED-2002-45, Experiment Package Fastener Types Simulation Report, January 31, 1967.

Since ground rules and configurations were still in a state of evolution at the date of submittal, this study will be expanded, updated, and resubmitted June 30, 1967.

3. Mobility Aids - This study developed methods and device concepts for both restraining and aiding movement of the astronaut within the S-IVB liquid hydrogen tank. Except for the concept of the centerline net tunnel for general translation and emergency exit, the mobility aids discussed herein were directed toward the specific tasks of sealing the tank penetrations. Each task was analyzed and the appropriate tethers, footholds, and handholds proposed.

This report, ED-2002-15, will be updated and expanded to include more generalized concepts and results of simulator testing, and will be resubmitted June 30, 1967.

4. Experiment Package Transfer Aids - An investigation and a comparison were made of concepts of transfer aids to be used by the astronauts for moving experiment packages from the launch stowage location into the S-IVB workshop. Sufficient layout development was performed to demonstrate feasibility of the concepts.

Eight concepts using pulleys, slide wires, tracks, and extendible tubes, either singly or in combination, were proposed. Since the experiment packages were considered to be mounted external to the AM during this study, these concepts were directed toward the capability of transferring and immediately storing all packages in the unpressurized liquid hydrogen tank.

This report, ED-2002-13, will be updated and resubmitted June 30, 1967, to incorporate additional concepts based on stowage of experiments within the MDA and results of simulator testing.

5. Passivation System Failure Analysis - The OWS passivation procedure, as known on January 3, 1967, was investigated in a single-point failure analysis regarding its impact on crew safety. Also, methods for improving the procedure were investigated.

Results of the study indicated numerous failures that could result in abort of the mission and loss of the OWS, but none were identified that would constitute an immediate hazard to crew safety. The nature of the major failures involved was pressure increases of vessels that fail to vent. These failures are classified as slow hazards and allow adequate time for crew action.

Recommendations concerning the passivation procedure included (1) incorporation of two separate command systems -- one automatic and one remotely controlled; (2) incorporation of a logic-sensing differential pressure measurement across the liquid oxygen and liquid hydrogen tanks; (3) installing a backup means to vent the liquid oxygen tank pressurization helium and J2 control helium; (4) delaying the venting of the J2 engine control helium for 5 hours; and (5) an investigation be conducted to evaluate a liquid hydrogen dump through the J2 engine.

6. Prediction of the Effects Produced by Dumping Residual Liquid Oxygen through the J2 Engine in Space - This study was performed to estimate the thrust produced when liquid oxygen is dumped through the J2 engine during the passivation procedure.

Results of thrust, specific impulse, and total impulse were plotted as a function of system impedance. For a liquid oxygen dump with no pump impedance, a thrust of 2,227 pounds was calculated. Since the study was reported, an estimate of system impedance has resulted in a thrust prediction of 1,700 pounds, a total impulse of 59,700 lb/sec, and a specific impulse of 14.7 seconds.

7. Revisit and Reactivation Study - A study report will document the requirements and activities necessary to revisit and reactivate the S-IVB orbital workshop after it has been stored in orbit for a

period of between three to six months. The study will include methods and recommendations for resupply of commodities, refurbishment for reactivation, and additional experiments to increase the useful life of the space station.

Since sufficient ground rules and data were not available during the period covered by the program report, submittal of this report, ED-2002-23, has been rescheduled for June 30, 1967.

C. MISSION OPERATIONS AND SUPPORT

Studies were performed in the mission operations area to provide input to other documentation and to better define mission requirements to compare with ground capability. These studies are summarized in this section.

1. Display and Control Criteria - ED-2002-18 presents the criteria that will be used to develop the requirements for the AAP mission displays and controls for the airborne vehicle, mission control center, and other ground control centers. Included are design requirements to use the available communication channels and MSFN. Data stripped from the communication channel are classified as real-time data, near-real-time data, and playback data.

2. Use of A/RIA as Relays - ED-2002-77 - Use of the Apollo/Range-Instrumented Aircraft (A/RIA) as Relays for Apollo Applications Missions, describes the study that was performed to determine the present capabilities of the A/RIA fleet and to define modifications required to support AAP missions.

The report describes the communications capability of the A/RIA and makes recommendations for changes needed to use the aircraft as telemetry relays in support of AAP missions. The changes would result in increased contact time between spacecraft and ground stations during low earth orbital missions.

An aircraft communication and instrumentation summary is included that lists the characteristics of the major blocks of equipment presently used. A projected aircraft communication and instrumentation summary is also included that lists the additional equipment required for several degrees of AAP mission support.

The main conclusion of this study is that the A/RIA aircraft can support AAP missions if they are supplied with a telemetry relay capability.

3. Command Station Display and Control - A study was performed to analyze the information and control needs of the command pilot imposed by the mission and conduct of experiments.

The report, ED-2002-82, analyzes the displays and controls required to support the experiments and subsystem add-ons for possible command pilot action.

The major conclusion in the report is a recommendation to include a new panel in the CM with the displays and controls necessary for optimum command pilot performance.

4. Use of MSFN Ship Stations - ED-2002-78, Description of MSFN Ship Stations and Their Potential Use for AAP Missions, describes the study performed to determine the present capabilities of the MSFN ships and to define growth requirements necessary to support AAP missions.

This document is divided into three major parts. The first part is a general description of the present capability and use of each ship and its applicability to the Apollo Applications Program. The second part is a detailed description of the ships' major data and tracking subsystems and the particular subsystems allotted to each ship. The third part discusses potential uses of the ships in the Apollo Applications Program.

The main conclusion of the study is that the ships can serve as a useful supplement to land-based stations.

D. COMPUTER PROGRAMS

Several math models were delivered under this contract. These models are:

1) Grouping analysis model (GAM) (Program MD 207) - ED-2003-2, ED-2004-2;
2) Orbit position analysis model (OPAM) (Program MD 208) - ED-2003-3, ED-2004-3;
3) Scheduling analysis model (SAM) (Program MD 214) - ED-2003-4, ED-2004-4;
4) AAP effectiveness model (Program MD 215) - ED-2003-6, ED-2004-6;
5) AAP cost model (Program MD 217) - ED-2003-5, ED-2004-5;
6) AAP data bank (Programs EA 024 and UA 003) - ED-2003-1, ED-2004-1.

Two forms of documentation were furnished to NASA on the above models during the Phase C contract period. ED-2003 reports consisted of single copies of the source program card decks and listings along with input data card decks for a sample problem for computer test. A listing of the program output for the test case was also included. ED-2004 reports consist of the program description, including the mathematical bases of computations.

1. Grouping Analysis Model (GAM) - The purpose of the grouping analysis model is to provide a tool to rapidly determine the characteristics of optimum experiment groups. These groups are determined by a mathematical logic that selects physically and logically compatible experiments so that stated criteria may be maximized. These criteria may be the maximum value of the experiment group, minimum cost, or perhaps the maximum number of experiments.

The model considers such experiment characteristics as weight, volume, and energy requirements, and the associated spacecraft constraints. It also considers such more complex experiment relationships as complementary value (where experiment results may correlate, hence, are more valuable together than separated) and common equipment use with the attendant advantages of weight and volume reduction.

The model output is identification of all possible experiment groups consistent with the input carrier constraints.

2. Orbit Position Analysis Model (OPAM) - The orbit position analysis model uses orbit equations to determine position and time relationships with respect to input ground station locations and produces a plan of orbit opportunities for performing communications and experiments involving remote earth sensors. This is accomplished by inputting the orbit altitude and inclination, and the latitude, longitude, and point of first equator crossing. The latitude, longitude, and minimum angles above the horizon for contact with communication stations and for experiment targets are also input. The model computes rise and set times of the spacecraft with respect to the cone of visibility for each station. The time of entrance into the cone of visibility and the time within the cone are produced by the model as outputs. In addition, Greenwich mean time, orbit number, and distance of closest approach are output. Results are provided in both digital and graphic form. Summary tables of total time in the cone of visibility for each station are also output. This results in a flight plan for orbit-constrained activities. This plan shows the available ground monitoring and data-link time and a measure of the time between sites

for experiment activity. Experiments requiring ground monitoring must be performed over selected sites and some communication opportunities may be skipped to provide more effective experiment times.

3. Scheduling Analysis Model (SAM) - This model determines a timeline type schedule of a specified set of experiments, with constant resource constraints applied throughout the entire flight period. In addition, astronaut sleep and watch cycles can be scheduled. Inputs to the model are, in addition to experiment data, schedule windows for both experiments and astronaut sleep and watch cycles. These windows are described either periodically or by actual listing.

The decision-making criteria for choosing between two conflicting experiments at a particular time are based on an urgency function that reflects first the need to schedule more important events early in the event of a mission abort and, second, reflects the importance of not missing a necessary scheduling window for any experiment.

Logical structuring of the model is based on an algorithm that performs the scheduling chronologically with look-ahead capability limited only by time and computer storage constraints. The allocating logic of the model is performed by the application of a linear programing process for zero-one variables, which yields a set of the "n" best solutions rather than just one.

4. Effectiveness Model - The model uses a Monte Carlo approach to simulate the in-flight performance of the experiments. It calculates failure times based on the reliabilities of equipment used in the experiments. Calculations are also made of failures due to subsystems, solar flares, meteor punctures, and astronaut illness. Using a schedule obtained from the scheduling analysis model, the failure calendar is examined to determine the impact on expected experiment results. The measure of effectiveness is proportional to the ratio of simulated experiment on-time to the scheduled on-time. The proportionality constant is a number that compares the relative value of completing the various experiments. It may also be a measure of the data value of each experiment. The achieved reliability of all equipment, experiments, and subsystems may be measured.

5. Cost Model - The cost model provides a means for inputting costs associated with experiment integration.

The outputs of the cost model are total program cost, development cost, facility cost, and operations cost, distributed as a function of time. Results of the cost analysis are combined with results of the system effectiveness analysis to provide such measures of cost/effectiveness as data value achieved per dollar.

6. AAP Data Bank - A data bank has been established to facilitate collecting, maintaining, retrieving, and reporting data concerning experiments, spacecraft, and missions. The data bank's function is twofold:

1) To provide capability of selecting certain data for direct input to the computer models;
2) To provide reports using a generalized report generator.

Experiment, spacecraft, and mission data are all stored on punched cards that are read onto a tape for storage. The data are periodically printed in the form of a data bank report. This report picks up all modifications and corrections as well as new entries into the data bank.

Initial deposits into the bank are made by submitting a set of data on an experiment or mission to keypunch. A total of 139 items are currently being used. However, the number can be increased to any number with only minor modification.

Reports consisting of the entire data bank or of selected entries can be obtained through use of a generalized report generator.

The Bendix Corporations's AAP team located at the Martin Marietta Denver facility is an integral part of the total project. Bendix activity areas include engineering, experiment analysis, industrial resources, quality and reliability, program management, and business management.

This chapter summarizes the Bendix studies performed during this contract period. Bendix reports documenting these studies are delivered to the Martin Marietta AAP project organization and are identified with a BD prefix. A BD listing is updated monthly and these listings are made available to the appropriate laboratories at MSFC.

A. ENGINEERING

1. Communications - During this contract period, 39 reports were issued. They primarily covered communication problems associated with Flights AAP-1 thru -4. Typical problems are cluster configuration antenna interference, data dump time-lines, and MSFN use. Studies were performed on techniques for increasing carrier-to-ground contact time by using Apollo/Range-Instrumented Aircraft (A/RIA) and MSFN ship stations, and for determining the capabilities and requirements of the uplink command system.

The reports representative of the analyses conducted are tabulated below.

BD No.	Title	No. of Pages
1057	Apollo Space Suit Communication System Existing Capability	4
1058	Communication and Tracking Requirements and Capability for DRMD Mission 209	5
1059	NASCOM Network	5
1060	Study on Use of Apollo/Range-Instrumented Aircraft as Relays for S/AA Missions	28
1061	Apollo/Range Instrumented Aircraft Communications and Instrumentation Equipment	288
1063	Data for Mission 209 DRMD Add-On Requirements (Comm)	7
1068	Communication Configuration for Electromagnetic Radiation Experiment Pack	3

BD No.	Title	No. of Pages
1069	Communication Add-On Modules for Mission 510 Special Tasks	2
1070	Antenna Interference Problems on the Cluster	4
1072	Spacecraft Data Dump Schedule for Flight S/AA 2 (Input to DRMD)	62
1074	Communication Subsystem ATM/EO-2	11
1078	RF Systems Study for the Cluster Configuration	28
1080	Utilization of MSFN Ground Stations and Equipment for Flight AAP-1	8
1081	Utilization of MSFN Ground Stations and Equipment for Flight AAP-2	25
1082	Utilization of MSFN Ground Stations and Equipment for Flight AAP-3	8
1083	Utilization of MSFN Ground Stations and Equipment for Flight AAP-4	56
1085	Ship Communication and Instrument Capability and Requirements	309
1092	Cluster Vehicle Antenna Coverage	24
1093	Cluster Voice Communication Analysis	9
1094	On-Orbit Command Required for Flights AAP-1 thru -4	7

2. Guidance and Control (G&C) - Special emphasis was placed on ATM pointing-accuracy studies. A comprehensive control system analysis and detailed computer simulation was conducted to determine the pointing accuracy that could be achieved with the ATM hard-mounted to the cluster. An additional analysis and simulation was conducted to determine the accuracy that could be achieved by employing the fine-pointing control system used in conjunction with a limited flexible pivot ATM vernier pointing control system. The two studies were summarized in BD-2063 and BD-2064, respectively.

Other areas of G&C activity included fuel consumption estimates required for various modes and experiment operations, configuration of supplemental or modified G&C systems, and computer simulations of various gravity-gradient-stabilized configurations. Thirty G&C reports were written during this contract period. Those tabulated on the following page are typical of the studies conducted.

BD No.	Title	No. of Pages
2036	Control Studies on Gravity-Gradient Stability and ATM Pointing Accuracy	41
2037	Control Studies on the LM/ATM Control Moment Gyro System	10
2039	Long-Term Attitude Time Histories for the Combined Mission Configuration II	2
2044	LM/ATM Three-Axis Simulation Hard-Mounted Configuration	17
2045	Initial Results of Linear Stability Analysis for CMG-Controlled Cluster	22
2046	Description of the Single-Axis Simulation Model for the CMG-Controlled Cluster	5
2047	Initial Results of the Single-Axis Accuracy Study for the CMG-Controlled Cluster	3
2048	Hardware Characteristics for the ATM Control Studies	10
2051	Crew Motion Data for Use in ATM Control System Accuracy Studies	13
2053	Infrared Horizon-Sensing Techniques and Implementation	25
2054	Long-Term Altitude Time Histories for Missions Involving the Deactivated Orbital Workshop	7
2055	Effect of Thruster Variations during Carrier Spinup	12
2056	Interim Results for the CMG-Controlled Cluster	10
2058	ATM Vernier Control System Mechanization Details	6
2061	Considerations for Using CMG for Performing Cluster Maneuvers	4
2063	Single-Axis Hard-Mounted ATM Control System Study	150
2064	Single-Axis Gimbaled ATM Control System Study	40

3. Data Management (DM) - The Bendix DM group supported the Martin Marietta DM group with analyses of experiment requirements and the compatibility of carrier DM equipment. Qualified add-ons were specified where required. Where necessary, changes were proposed for existing DM subsystems. In some cases, completely new subsystems were proposed for special experiment groupings such as EO-2 and EMR. Twenty-seven analysis reports have been issued in this contract period and those tabulated below are representative of the analyses conducted.

BD No.	Title	No. of Pages
3039	IU Data Management Capability vs Flight 209 Data Management Requirements	3
3040	Saturn PCM Digital Data Acquisition System	6
3042	Mission 209 Interface Requirements	9
3043	Mission 209 Ground Control	5
3044	Mission 209 Data Management Timing Correlation	2
3045	Data Management System for Electromagnetic Radiation Experiments	6
3047	Mission 510 Data Management Considerations	5
3053	Data Management Report, Cluster Compatibility Analysis	35
3054	Data Management Input to Flight S/AA 2 DRMD	11
3057	Saturn Telemetry Oscillator Assembly	5
3058	Data Management Inputs to Flight S/AA 1 DRMD	11
3060	Data Management Analysis of the EMR Experiments for Flights S/AA 4 and 5 Alternative Configurations	8
3061	Data Management Configuration Design Report for Flight AAP-3	12
3062	Data Management Configuration Design Report for Flight AAP-2	18
3063	Data Management Summary Analysis for Flights AAP-1 thru -37	20
3064	Phase D Proposed Study Tasks	2

4. Display and Control (D&C) - Various analyses of the D&C requirements necessary to support experiments, subsystem add-on equipment, and ground-based displays were conducted. These analyses were accomplished for numerous flights, missions, configurations, and concepts. The D&C group issued 19 reports during this period. The following reports are examples of their effort.

BD No.	Title	No. of Pages
4048	Display and Control Requirements for Experiment and Subsystems Add-Ons for Mission 209	19
4049A	Display and Control Capabilities for Mission 209	2
4051	Display and Control Input to Flight 209 Design Plan	27
4052	Display and Control Panel Layouts for Experiment and Subsystem Add-Ons for the Cluster Configuration (AM/MDA/S-IVB)	23
4053	Display and Control Analysis of Electromagnetic Experiment Package	3
4055	Display and Control S-IVB Passivation Requirements from the Airlock Module	3
4056A	Display and Control Input to the Cluster Configuration Compatibility Analysis	54
4058	Ground Display and Control Input to the DRMD for Mission 209 Flight S/AA 2	6
4060	Display and Control Input to the Feasibility Analysis of Combining EO-2 Experiments with the ATM Mission	17
4062	Display and Control Input to the EMR Experiment Feasibility Study	8
4063	Ground Display and Control Input to the DRMD for Flight S/AA 1	3
4066	Display and Control Command Pilot Action Analysis	
4067	Display and Control Interface Requirements for the Cluster Configuration	

B. EXPERIMENT ANALYSIS

Bendix Experiment Analysis personnel prepared 68 experiment analysis reports during the Phase C study. These analyses have been incorporated in the Experiment Requirements Document, Volumes I thru X (ED-2002-71). In addition to the experiment analyses, a document was prepared to describe tasks related to the integration of lunar surface missions (BD-5203).

The following tabulation lists experiments analyzed in this contract period. These reports fit a standard format that was developed early in the program. This format was designed to enable each functional group to readily locate the information it needs.

BD No.	Title
5136	Day-Night Camera S039
5137	Dielectric Tape Camera S-040
5138	Millimeter Wave Propagation S-041
5139	CO_2 Reduction D-017
5140	Heat Exchanger Service M-489
5141	Orbital Workshop Aritificial g
5142	Astronaut Extravehicular Activity and Hardware Evaluation
5143	Space Suits and Lunar Experiment Hardware
5144	Optical Communication M-446
5145	Fusible Material, Space Radiator T005
5146	Nondestructive Testing MSFC-29
5147	Atmosphere Survey
5148	Combined Space Effects on Nonmetallic Materials
5149	Suit Donning and Sleep Station Evaluation DO-19
5150	Evaluation of Alternative Restraints for Maintenance and Mobility DO-20
5151	Analysis of S021 - Airglow Photography DO-23
5152	Antenna Patterning MSFC-13
5153	Moderate-Depth Core Drilling (30-meter type)

BD No.	Title
5154	Nephelometer Experiment T003
5155	Penetrometer
5156	Moderate-Depth Core Drilling (1.5 and 3.0-meter type)
5157	Local Scientific Survey Module (LSSM)
5158	Lunar Mapping Photography M-401
5159	Ultraviolet (UV) Airglow Horizon Photography S-063
5160	Multiband Terrain Photography S-065
5161	Tidal Gravimeter (ESS)
5162	Corner Reflector (ESS)
5163	Star-Horizon Automatic Tracking
5164	X-Ray Astronomy S017
5165	Gamma Ray Spectrograph MSFC 53-A
5166	X-Ray Array MSFC 53-B
5167	UV Stellar Instrument MSFC 53-C
5168	Astronaut Maneuvering Unit DO-12
5169	Total Pressure Gage (ESS) M459F
5170	Total Radiation Dosimeter (ESS) M-459H
5171	Statement of Work, Cluster Configuration Compatibility Analysis
5172	Day-Night Camera S-039
5173	Trapped Particle Asymmetry Experiment S016
5174	Electric Field Meter (ESS) M-459J
5175	Optical Telescope (ESS) M-459M
5176	Infrared Temperature Sounding S043
5177	Near-IR Filter Wedge Spectrometer S045
5178	High-Resolution Infrared Spectroscopy S049
5179	Polarization Measurements S046
5180	Management of Atmospheric Structure by Refraction Star-Tracking Techniques S047
5181	UHF Sferics Detection S048
5182	Gamma-Ray and X-Ray Spectroscope MSFC 53-D

BD No.	Title
5183	UV Resonance Spectrophotometer (ESS) M459N
5184	Day-Night Camera-Image Orthcom Camera System
5185	Low-Energy Gamma-Ray Astrology Experiment
5186	Digitized Spark Chamber MSFC 53-E
5187	Multichannel Radiometer S060
5188	Integrated Maintenance DO-18
5189	Selective Chopper Radiometer S-057
5190	Cosmic Ray Telescope (ESS) M-459P
5191	Solar Wind Detector (ESS) M-459Q
5192	Laser Mapping and Ranging (ESS) M-450R
5193	Synoptic Terrain Photography S-005
5194	Synoptic Weather Photography S-006
5195	Measurement of Mechanical Properties MSFC-8
5196	Fuel Cell Power System MSFC-39
5197	X-Ray Astronomy Experiment S-027
5198	UV X-Ray Solar Photography S-020
5199	Navigation Traffic Control Techniques Experiment
5200	Orbital Evaluation of an Integrated Waste Collection and Processing System EJO-410
5201	UV Stellar Astronomy EFO-0102 S-019
5202	Precision Optical Tracking T018
5203	Integration Contractor Tasks on AAP Lunar Surface Exploration Missions
5204	Astronaut Maneuvering Evaluation

C. INDUSTRIAL RESOURCES

The Bendix Industrial Resources Group is completely integrated with the Martin Marietta organization. They participated in the development of facilities and manufacturing plans. In addition, they specified facility and manufacturing requirements for the subsystems and experiments that are Bendix responsibilities. They also worked with their Martin Marietta counterparts in establishing the group requirements and policies.

D. QUALITY AND RELIABILITY (Q&R)

The Bendix Q&R Group was also completely integrated with the Martin Marietta Q&R organization. They helped with planning and developing the reliability and quality assurance plan in PL 2008, Program Performance Requirements. In addition, they were also instrumental in establishing Q&R requirements and policies.

E. PROGRAM MANAGEMENT

During this six-month contract period, the Program Management Group participated in the development of the format for the contractual documents and helped Martin Marietta set up and maintain the AAP Library.

They also participated in the maintenance of the engineering release schedule, establishing and updating the network charts, and maintaining the control room charts.

F. BUSINESS MANAGEMENT

This group provided for the use of the Bendix Huntsville facility during Phase C, recorded and distributed the Bendix documents and reports that were delivered to Martin Marietta, and also those received from Martin Marietta. They also coordinated the Bendix effort in the preparation of the Bendix cost estimates and negotiated the Phase D contract with Martin Marietta Corporation.

A. CONTRACTUAL DATA SUBMITTALS

This section lists items of contractual data that were submitted to MSFC during this reporting period.

ED-2002-2, Carrier Selection Study, October 7, 1966

Candidate carriers for AAP missions were analyzed and recommendations made. The results of this study are contained in Technical Study and Analysis Report, ED-2002-2, which was submitted under DRL Line Item 20 on October 7, 1966. Seven volumes of reference data were included with this report.

ED-2002-1, Preliminary Facility Investigation Results, October 7, 1966

This report was submitted under DRL Line Items 20 and 13 on October 7, 1966. The report comprises the results of an investigation into the factors governing location of the payload integration facility. A basic volume summarizes results and presents recommendations. Three volumes of reference data support the conclusions.

ED-2003-2 and ED-2004-2, Grouping Analysis Model (GAM), October 10, 1966

ED-2003-3 and ED-2004-3, Orbital Position Analysis Model (OPAM), October 10, 1966

ED-2003-4 and ED-2004-4, Scheduling Analysis Model (SAM), November 10, 1966

ED-2003-5 and ED-2004-5, Cost Model, November 10, 1966

The four computer program documents and associated punched cards were submitted under DRL Line Items 41 and 42. These are additional parts of a set of math models designed to optimize experiment groupings on AAP carriers.

CX-200300, Payload Development Document, October 7, 1966

This document was scheduled as a nine-month output, but its utility for aiding experiment development made early availability desirable. Consequently, a preliminary version was submitted under DRL Line Item 17 on October 7, 1966. The current version is necessarily incomplete, but it provides a framework on which to build, via revision pages, during the next six months.

PL 2019, Configuration Management Plan, October 7, 1966

Like the Payload Development Document, the need for an early version of this plan was apparent. Since some alternative missions must be defined by specification before completion of the nine-month documentation, a baseline must be available for configuration management and change control. A preliminary version of this plan was, therefore, submitted on October 7, 1966, under DRL Line Item 11. This draft will also help define any Martin Marietta participation in early mission integration.

ED-2002-5, Payload Integration Facility Test Plan, October 12, 1966

This technical study and analysis report, submitted under DRL Line Item 20 on October 21, 1966, delineates the basis for the facility and ground support requirements at the payload integration facility. It also provides a test planning status report for MSFC's use as a management tool, and can be used to determine requirements for design, build, and/or procurement of test specimens for conducting the program.

ED-2002-4, Experiment Data Handbook, October 25, 1966

This technical study and analysis report was submitted under DRL Line Item 20 on October 25, 1966, and supports the carrier selection study. It contains preliminary experiment interface requirements and preliminary experiment analyses for the experiments considered in the carrier selection study. As available information increases, this handbook will be reissued to incorporate the new information.

PL 2001 (Rev A), Definition Phase Program Plan, November 3, 1966

The program plan was revised to define the work to be accomplished during the second contract period based on the experience gained during the initial period and further direction from MSFC. This revision was submitted on November 3, 1966, under DRL Line Item 1 and, on approval, will be used to monitor contractor performance.

ED-2001, Design Reference Mission Document, Combined Mission - Flight SA 209, November 14, 1966

A preliminary DRMD for Flight SA 209 of the combined mission was submitted on November 14, 1966, for MSFC review and comments.

The six-volume updated version of the preliminary DRMD was submitted on January 26, 1967, under DRL Line Item 19. The trajectory tab run was submitted with the review copy on January 9, 1967.

ED-2002-6, Sequence Analysis, Activation of Mission 209 Orbital Workshop, November 14, 1966

This special study report was submitted under DRL Line Item 20 on November 14, 1966. It represents completion of Task I of the system design integration study for the S-IVB orbital workshop to analyze the step-by-step activation requirements for the S-IVB OWS. Results of additional study conducted on the first task of the Orbital Workshop Integration Study, ED-2002-6 (Rev 4), was submitted on January 11, 1967, as a revision to ED-2002-6.

RS 200000, General Specification for Performance and Design Requirements for AAP Combined Mission 209/210/211/212, November 14, 1966

A draft copy of this specification was submitted on November 14, 1966, for MSFC review before final publication. This specification defines the performance and design requirements for the AAP combined mission and establishes requirements for design, development, and test of all elements of the mission beyond the scope of the basic Apollo program. The final specification will be submitted as a part of the Flight 209 early documentation.

ED-2007, Problems Associated with Condensation within the S-IVB Spent Stage

ED-2002-7, Analysis of Crew Comfort Requirements

ED-2002-8, Analysis of Effect of Meteoroid Shields on Thermal Balance

ED-2002-10, Active Thermal Control Systems for the S-IVB Workshop

Preliminary study reports were submitted on the preliminary results of studies conducted on Tasks I, II, III, and V of the S-IVB thermal control study. Task I report was submitted on November 2, 1966, Task II and III reports on November 15, 1966, and Task V report on November 30, 1966. Additional information on the S-IVB condensation problems was submitted in ED-2002-9 on November 21, 1966. This report, A Study of Condensation within the S-IVB Spent Stage, supplements ED-2007. An addendum to ED-2002-10 was submitted on January 4, 1967, with a clarification report being submitted on February 9, 1967. Additional results of control and condensation studies were submitted in ED-2002-20 on January 4, 1967, and in ED-2002-47 on February 9, 1967. The final report was submitted on March 6, 1967.

PL 2002-1, Design Plan for Combined Mission Flight 209, November 28, 1966

A preliminary draft of the Design Plan for Flight 209 of the combined mission was submitted on November 28, 1966, for MSFC review. The final draft of this document will be submitted as a part of the Flight AAP-209 early documentation.

Configuration Management Plan for Flight SA 209, November 28, 1966

A draft of a Configuration Management Plan for Flight SA 209 was prepared to assist P&VE in the integration of SA 209. This plan was submitted on November 28, 1966. The plan shows the use of existing MSFC systems to integrate experiments into their respective carrier vehicles.

PL 2023, Mission 209 Detail Task Plan, November 30, 1966

Part of the early documentation for Flight SA 209, this detailed task plan sets forth the tasks necessary to successfully accomplish Flight SA 209. This plan was submitted November 30, 1966, under DRL Line Item 20.

Report 42-1001, Flight SA 209 and 210 Command Module Data Return Feasibility Study, December 3, 1966

A study was undertaken in response to a request from MSFC to determine the experiment return weight, volume, and location within the SA 210 command module. The results of this study were documented in a special report, 42-1001, submitted on December 3, 1966.

ED-2003-4 (Rev A), Scheduling Analysis Model (SAM), December 7, 1966

ED-2003-3 (Rev A), Orbital Position Analysis Model (OPAM), December 7, 1966

Improved computer programs were developed for the SAM and OPAM. Replacement source decks for these two models were submitted under DRL Line Item 41 on December 7, 1966.

An updated source deck and tabulation listing, ED-2003-4 (Rev B), was submitted on February 14, 1967, containing recent logic modifications and a set of data input cards representing a test run on SAM for Mission E0-02. The Computer Data Program Document (ED-2003-1) submitted March 15, 1967, replaced the previously delivered GE 625 version with the IBM 7094 version.

ED-2002-11, Experiment Selection for Synchronous Orbit, December 14, 1966

This report contained the results of the analyses of the experiments selected for the synchronous orbit missions, SA 510 and SA 515. It was submitted under DRL Line Item 20 on December 14, 1966.

Report 42-0001, Cluster Configuration Compatibility Analysis, December 22, 1966

This informal report, consisting of two volumes with a set of supporting viewgraphs, was submitted on December 19 and December 22, 1966. It was prepared as a result of a request from MSFC to analyze the compatibility of experiments with the vehicles in the cluster configuration.

CX-200300 (Rev 12/27/66), S/AA Experimenters Guide, December 27, 1966

This document was previously submitted under DRL Line Item 17 as a preliminary payload development document. That document was updated to include current information and resubmitted as an Experimenters Guide under DRL Line Item 17 in accordance with instructions from MSFC on December 27, 1966.

Orbital Workshop Project Development Plan, December 30, 1966

This is a rough draft of a project development plan (PDP) for the orbital workshop. It was prepared in consultation with MSFC personnel to provide a framework for development of the final OWS PDP and submitted on December 30, 1966.

ED-2002-19, Determine Temperature Gradients in the S-IVB Orbital Workshop, January 4, 1967

This preliminary special report contains the results of the study conducted to determine atmosphere temperature gradients in the S-IVB OWS. Submittal was made on January 4, 1967, in accordance with Task IV of the revised work statement.

Tabular Experiment ICD Tree and Group I ICDs for Flight AAP-2, January 6, 1967

These documents, submitted on January 6, 1967, for review, consist of the tabular experiment interface control document (ICD) tree and the Group I experiment ICDs for AAP-2, for the second part of the Experimenters Guide for AAP-2.

Feasibility Analysis of Combining APP-A Experiments with ATM, January 10, 1967

This special report updates the previously submitted feasibility analysis on ATM/EO-2 combinations and was submitted on January 10, 1967.

ED-2002-13, Experiment Package Transfer Aids for Mission 209, January 11, 1967

ED-2002-15, Mobility Aids in S-IVB Tank, January 11, 1967

These preliminary reports, submitted January 11, 1967, covered segments of the study of corollary experiment integration for the Mission 209 orbital workshop.

ED-2002-17, Multiple Docking Adapter Structural Design Requirements, January 11, 1967

This report covers results of a study of structural design requirements for the multiple docking adapter. The report was submitted on January 11, 1967.

ED-2002-25, S-IVB LH_2 Feedline Tank Outlet Sealing Operation Simulation Report, January 12, 1967

This study of sealing the S-IVB feedline tank outlet was conducted using the Martin Marietta zero-g simulator. It was submitted January 12, 1967, under DRL Line Item 20.

ED-2002-24, Crew Safety Analysis, Combined Mission, January 12, 1967

This special study reports on crew safety considerations for Mission 209 in accordance with the work statement for human factors engineering support for Mission 209. The document was submitted for review on January 12, 1967.

ED-2002-21, Analysis of Fire Detection for the Orbital Workshop, January 12, 1967

This preliminary study, reporting on the results of analyzing the fire-detection requirements for the S-IVB OWS, was submitted on January 12, 1967. As a result of requested reoriented emphasis after review of the draft copy by NASA personnel, Chapter V and an addendum to the report contain the requirements for fire detection resulting from meteoroid penetration.

ED-2002-28, Mission Requirements Document, Cluster Configuration Mission, Flights S/AA 2, January 19, 1967

This report on mission requirements for AAP-2 was submitted on January 19, 1967, under DRL Line Item 20.

Group 2 ICDs for Flight AAP-2, January 20, 1967

This report, submitted on January 20, 1967, is an additional part of the Mission 209 payload development documentation and covers the five experiment ICDs for AAP-2 in Group 2, comprising three separate sections consisting of the functional, physical, and procedural interface requirements for each of the experiments.

ED-2002-26, Hardware Requirements Document, Flight AAP-2, January 20, 1967

This document, which sets forth the design requirements for ground and flight hardware for AAP-2, was submitted on January 20, 1967, under DRL Line Item 20.

Cluster Compatibility Analysis, Electric Power System for AAP 1/2,3/4, January 20, 1967

This is a draft copy of the report covering the analysis of power system requirements for the cluster configuration and was submitted on January 20, 1967.

<u>CX-200300, AAP Experimenters Guide, January 20, 1967</u>

This modification of Document CX-200300 incorporated revisions and was reprinted in accordance with an MSFC request. Submittal was made on January 20, 1967. Subsequent submittals included revised pages and the typed originals.

<u>Use of Common Propellants in the SM-RCS and SPS, January 25, 1967</u>

This document, submitted on January 25, 1967, contained information on use of common propellants in the SM-RCS and SPS to increase the capability of SM-RCS by supplying propellants from the SPS tanks. A tradeoff study previously performed was included for information concerning methods of increasing the RCS propellant supply capability.

<u>Reuse of EO-0 and LO-0 Experiment Package, January 25, 1967</u>

This draft study report, submitted January 25, 1967, is an extension of the preliminary report on reuse of the EO-0/LO-0 experiment package. It contains the results of analysis of EVA and reactivation. This draft report was included in the final report submitted February 8, 1967.

<u>ED-2002-30, Electromagnetic Radiation Experiment Feasibility Analysis, January 26, 1967</u>

Results of the feasibility analysis conducted on electromagnetic experiments was submitted January 26, 1967, under DRL Line Item 20. Additional backup data have been compiled and are available on request.

<u>ED-2002-32, Proposed Fire Detection System and Test Plan, January 26, 1967</u>

This preliminary report on fire detection systems for the S-IVB OWS was submitted on January 26, 1967.

<u>PL 2016, Flight AAP-2 Facility Plan, January 30, 1967</u>

This is a part of the early documentation requirements for AAP-2 and was submitted under DRL Line Item 13 on January 30, 1967.

PR 2005-4, Periodic Review Report, January 31, 1967

This report contains the minutes of the January 26, 1967, informal review held at Martin Marietta Corporation, Denver, Colorado. Submittal was on January 31, 1967, under DRL Line Item 9.

ED-2002-12, Quick-Release Fasteners for Space Application, January 31, 1967

ED-2002-22, Proposed Modifications to Stage S-IVB LH_2 Tank Orbital Workshop, January 31, 1967

These reports cover the remaining segments of the corollary experiment integration for Mission 209 orbital workshop study. These reports completed Task II of the system design integration study. Submittal was on January 31, 1967.

ED-2002-33, Orbital Workshop General Test Plan, January 31, 1967

This test plan was submitted under DRL Line Item 20 on January 31, 1967.

ED-2002-45, Experiment Package Fastener Types Simulation Report, February 2, 1967

This technical study and analysis report covering simulation of experiment package fasteners was submitted on February 2, 1967 under DRL Line Item 20.

ED-2002-34, Orbital Workshop Training Plan, February 2, 1967

This technical study and analysis report was submitted on February 2, 1967, under DRL Line Item 20.

Group 3 ICDs for Flight AAP-2, February 3, 1967

This additional part of the Mission 209 payload development documentation was submitted on February 3, 1967, under DRL Line Item 17. This effort covered five experiment ICDs in Group 3, including the functional, physical, and procedural interface requirements combined into a single document for each experiment.

ED-2002-27, Specification for S-IVB Stage for Use as Orbital Workshop, February 8, 1967

This specification detailing the modification required to permit use of the S-IVB as an OWS included the latest information as generated during internal design reviews held during the first week of February. It was submitted on February 8, 1967, in compliance with DRL Line Item 20.

ED-2002-46, Study and Analysis of EO-0 and LO-0 Experiment Groups, February 9, 1967

This report, submitted on February 9, 1967, under DRL Line Item 20, covers the results of studies conducted to establish the interface requirements for EO-0 and LO-0 experiment packages for integration on the LM&SS rack, and the reuse/resupply problems of the experiments.

ED-2002-50, Crew Operations Requirements for Combined Mission Cluster, February 13, 1967

This special report, which constitutes a basic reference for human engineering, operations, training, and simulation, was submitted on February 13, 1967, as a preliminary document for review and comment.

ED-2002-24 (Ref A), Crew Safety Analysis, Cluster Mission Flight AAP-2, February 14, 1967

This submittal on February 14, 1967, under DRL Line Item 20 represented the final report on crew safety analysis for Cluster Mission AAP-2.

Group 4 ICDs for Flight AAP-2, February 16, 1967

This final submission of the Mission 209 payload development documentation was made on February 16, 1967, under DRL Line Item 17 and covered the functional, physical, and procedural interface requirements in five experiment ICDs in Group 4.

ED-2002-48, Design Review Report, February 16, 1967

Submitted on February 16, 1967, under DRL Line Item 20, this report covered the significant areas of design reviews held January 30 thru February 6, 1967.

ED-2002-36, Crew Support Equipment Design Requirements, February 17, 1967

This report was submitted on February 17, 1967, and covers the crew support design requirements for the cluster configuration in accordance with the human factors engineering support for Mission 209.

ED-2002-37, Fire Detection System Equipment Specification, February 22, 1967

This preliminary study report consists of a procurement specification and was submitted on February 22, 1967.

ED-2002-29, Human Engineering Test and Simulation Program Plan, February 22, 1967

This technical study and analysis report was submitted on February 22, 1967, in compliance with DRL Line Item 20.

ED-2002-55, AAP Resupply Report, February 28, 1967

This report, covering the AAP resupply analysis, was submitted on February 28, 1967, under DRL Line Item 20.

S-IVB Stage Passivation, February 27, 1967

This report, covering the prediction of effects produced by dumping residual lox through the J2 engine into space, was submitted on February 27, 1967. A failure analysis of the passivation procedure was included for information purposes only.

ED-2002-56, Crew Schedule Effects on Experiment Time Availability, February 27, 1967

This special study report, covering crew schedules and experiment time availability effects, was submitted on February 27, 1967, under DRL Line Item 20.

ED-2002-43, Meteoroid Vulnerability Analysis, February 28, 1967

This special study report, submitted on February 28, 1967, under DRL Line Item 20, summarizes studies of the vulnerability of the S-IVB workshop and multiple docking adapter to meteoroid environment.

ED-2001-2, Design Reference Mission Document, Cluster Configuration Mission, Flight AAP-1, February 28, 1967

This six-volume document, including copies of the trajectory tab run (Confidential), was submitted on February 28, 1967, in compliance with DRL Line Item 19.

ED-2002-54, Chill Pump Operation Simulation Report, March 2, 1967

This study report, covering the investigation of astronaut restraint devices necessary to seal off the S-IVB chill pump vent during OWS activation, was submitted under DRL Line Item 20 on March 2, 1967.

ED-2002-62, Methods of Eliminating EVA from EO-0/LO-0 Experiment Group, March 8, 1967

Submitted on March 8, 1967, under DRL Line Item 20, this report establishes a concept for elimination of EVA from LO-0.

ED-2002-51, Docking Loads and Orbit Transfer Maneuver Study, March 10, 1967

This special study report was submitted on March 10, 1967, under DRL Line Item 20.

ED-2002-63, Investigation of Experiment Locations, March 15, 1967

This special study report covering the results of an analysis of relocating six experiments assigned to the cluster configuration, Flights AAP-1 thru -4, was submitted under DRL Line Item 20 on March 15, 1967.

ED-2002-58, Mission Requirements Document, Cluster Configuration, Mission Flight AAP-4, March 16, 1967

This report, establishing the general mission requirements for AAP-4, was submitted on March 16, 1967, under DRL Line Item 20.

ED-2002-64, Cluster Electromagnetic Compatibility, March 16, 1967

Submitted on March 16, 1967, under DRL Line Item 20, this report covers the EMC testing requirements of the cluster configuration.

ED-2002-74, Forward and Aft End Heat Leaks, S-IVB Orbital Workshop, March 27, 1967

This report containing conclusions concerning heat leaks on the ends of the S-IVB orbital workshop was submitted March 27, 1967, under DRL Line Item 20.

ED-2002-70, Flight AAP-4 Facility Plan, March 30, 1967

This report on AAP-4 facility requirements was submitted under DRL Line Item 20 on March 30, 1967.

ED-2002-86, Command Module Display and Control Panel Requirements, March 30, 1967

Submitted on March 30, 1967, under DRL Line Item 20, this report provides the results of examining the crew/system interfaces to determine design requirements for displays and controls.

B. OTHER DELIVERED REPORTS

In addition to the foregoing technical study reports and documents, the program status reports and miscellaneous contractual reports listed in this section were also submitted during this program period.

PR 2003-1, Program Report (First Three-Month Period), October 7, 1966

This report included the September monthly progress report and the quarterly progress report required by the "Reports of Work" clause of the Contract General Provisions. This report was submitted under DRL Line Item 6.

PR 2004-1, Presentation Material, October 26, 1966

The first formal program review was submitted under DRL Line Item 7.

PR 2005-3, Periodic Review Report, October 31, 1966

The October 26, 1966, formal review was submitted under DRL Line Item 9.

ED-2002-66, Process Analysis for Crew Station Design, Flight AAP-2, March 16, 1967

This report, providing the results of a study and analysis of location, setup, and operating procedures for experiments on AAP-2, was submitted March 16, 1967, under DRL Line Item 20.

ED-2002-65, Flights AAP-3 and -4 Task Analysis, March 20, 1967

This task analysis report was submitted March 20, 1967, under DRL Line Item 20.

ED-2002-68, Cluster Verification Test Justification and Feasibility, March 20, 1967

This preliminary report was submitted March 20, 1967, under DRL Line Item 20.

ED-2002-69, Configuration Trade Study Cluster Verification Test, March 20, 1967

This report was submitted on March 20, 1967, under DRL Line Item 20.

ED-2002-42, Radiation Analysis for the Apollo Applications Program, March 21, 1967

This report covers the radiation environments that will be encountered on the early AAP missions and was submitted on March 21, 1967 under DRL Line Item 20.

ED-2001-3, Design Reference Mission Document, Cluster Configuration, Flight AAP-3, March 23, 1967

This six-volume document was submitted on March 23, 1967, under DRL Line Item 20.

ED-2001-2, Design Reference Mission Document, Cluster Configuration Mission, Flight AAP-1, March 23, 1967

This six-volume document was submitted under DRL Line Item 20 on March 23, 1967.

PR 2002-3, Monthly Progress Report (October 1966), November 10, 1966

This report was submitted under DRL Line Item 5.

PR 2002-4, Monthly Progress Report (November 1966), December 7, 1966

This report was submitted under DRL Line Item 5.

PR 2003-2, Program Report (Second Three-Month Period), January 9, 1967

This report included the December 1966 monthly progress report and the quarterly progress report required by the "Reports of Work" clause of the Contract General Provisions. This report was submitted under DRL Line Item 6.

PR 2002-5, Monthly Progress Report (January 1967), February 7, 1967

This report was submitted under DRL Line Item 5.

PR 2002-6, Monthly Progress Report (February 1967), March 7, 1967

This report was submitted under DRL Line Item 5.

PR 2008-1, Labor Disputes Report (Report of Labor Union Negotiations), October 10, 1966

This report was submitted under DRL Line Item 34.

C. PROPOSAL DOCUMENTS

The proposal documents submitted April 7, 1967, under DRL Line Item 2 are tabulated below.

Document No.	Title
PL 2050	Cost Proposal
PL 2051	Program Summary
PL 2052	Technical Requirements Summary
PL 2053	Management Plan
PL 2054	Program Control Plan
PL 2055	Design and Development Plan (including Addenda A and B)

PL 2056	Technical Operations Plan (including Addenda A and B)
PL 2058	Program Performance Requirements

D. OTHER APRIL 7 SUBMITTALS

The following documents were also delivered April 7, 1967, under DRL Line Item 20.

Document No.	Title
ED-2002-59	Feasibility Study, Unassigned Missions
ED-2002-71	Experiment Requirements Document (10 Volumes)
PL 2002	Design Plan
PL 2002-1	Design Plan, Addendum 2
PL 2002-2	Design Plan, Addendum 1
PL 2002-3	Design Plan, Addendum 3
PL 2002-4	Design Plan, Addendum 4

E. DATA DELIVERIES BY APRIL 14

Data completed during the second contract period that will be delivered by April 14, 1967, to MSFC are tabulated below.

Document No.	Title
ED-2001	General DRMD
ED-2002-41	Final Fire Detection System Report
ED-2002-49	General Test Plan (Vol I) Subsystem Development Test Plan (Vol II) Payload Integration Development Test Plan (Vol III) Integration and Prelaunch Checkout Test Plan (Vol IV)
ED-2002-72	Ground Support Equipment Implementation Plan for AAP
ED-2002-73	Feasibility Study, Data Return Capsule
ED-2002-74	S-IVB Tank End Heat Leak

ED-2002-76	RF Systems Study for Cluster Configuration
ED-2002-77	Use of Apollo/Range-Instrumented Aircraft (A/RIA) as Relay for Saturn Apollo
ED-2002-79	MSFN Ground Station Utilization for Cluster Mission
ED-2002-80	Single-Axis Cluster ATM Pointing Accuracy Study, Hard-Mounted Case
ED-2002-81	Single-Axis Cluster ATM Pointing Accuracy Study, Gimbaled Case
ED-2002-82	Command Station Control and Display Tradeoff Analysis
ED-2002-84	AAP Reliability Models
RS200000	General Specification